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Research on the Content, Technological, and Pedagogical Knowledge (TPACK) of Chemistry Teachers During Remote Teaching in the Pandemic in the Light of Students' Perceptions

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Abstract

Aim/Purpose	The objective of this study is threefold: (i) investigate how a group of subjects see the relationship between the integration of content, pedagogical and technological knowledge of their chemistry teaching in light of the teaching practices developed during the pandemic; (ii) present a framework for the integration of digital technologies in chemical education; and (iii) integrate empirical research on teachers' relationship with technology in the remote classroom during the pandemic.
Background	The COVID-19 pandemic has imposed changes in the ways of teaching and learning and has affected educational contexts at all levels of education. While technology has been instrumental in providing access to education during the pandemic, it has also revealed a picture of serious technological inequality, especially among students. The adoption of technology in education is an old topic in Brazil but still requires studies and advances in the implementation of Information and Communication Technologies (ICT) in education. With

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regard to teaching Chemical Science, the study of the skills and knowledge that teachers need to carry out an effective and efficient integration of ICT in education is still a priority at any educational level.

Methodology The research method used was qualitative with an interpretive paradigm that involved 324 Licentiate and Baccalaureate students in Chemistry from public educational institutions in the five regions that make up the Brazilian territory. Data were collected through an online survey and, after being exported it was analyzed using Python software. In order to reduce the number of variables, exploratory factor analysis was carried out followed by a reliability analysis of the adopted factors, in addition to subsequent comparisons between the means related to the three factors for each of the categorical variables present in this work (Gender, Age, Region, Teacher Education, Period, and Course).

Contribution This article analyzes the perceptions of these chemistry students in Brazil regarding the effective integration of content, pedagogical and technological knowledge of their chemistry teachers during the pandemic. It also proposes a framework of a model constituted from the amalgamation between Johnstone's triangle and the conceptual structure TPACK whose aim is to teach chemistry by interrelating the macroscopic, symbolic, and submicroscopic levels incorporated into technologies.

Findings The results of this research allow us to conclude that of the three main knowledge areas proposed in the TPACK model, the field of Knowledge mostly Scientific of chemistry teachers (Factor 1) was pointed out as the most deficient when investigated in the light of the perceptions of the students. The model developed and presented in this study, which integrates TPACK into the Johnstone Triangle, proposed a theoretical framework that explains the integration of technology into the chemistry curriculum and gives teachers a very important role in its use and appropriation to facilitate the integration of technology in an effective way, thus adding improvements to the construction of chemical knowledge of their students.

Recommendations for Practitioners This study found that it is necessary for chemistry teachers to carry out training courses to improve the development of ICT-related skills and, consequently, to use the knowledge that composes the TPACK structure in interrelated ways so that chemical instructions can be used in a pedagogically appropriate manner and effectively to improve students' chemistry learning experience.

Recommendations for Researchers This study involved only higher education chemistry professors and students; therefore, future research is needed involving chemistry teachers from different levels of education to expand our results. In addition, the proposed model that integrates TPACK and Johnstone's Triangle can be reapplied and improved, and new theoretical and epistemological contributions can be added to the framework to improve the teaching and learning process of chemistry with the support of technologies.

Impact on Society The understanding of the TPACK of higher education chemistry teachers in Brazil can demonstrate weaknesses in the process of incorporating ICT in the classroom during the process of teaching and learning chemistry. Therefore, this research typology can be useful in supporting the development of ICT-related skills, consequently improving teachers' TPACK. On the other hand, such understanding, by promoting reflections on university chemistry curricula, endorses the need for teachers' continuing education as a healthy mechanism for a growing integration of technologies in their teaching practices. The

	proposed model has the potential to align discussions on the use of technology in teaching chemistry, considering the specificities that are inherent and indispensable to the understanding of chemical knowledge.
Future Research	Future research should be to further improve the use of the proposed model that integrates Johnstone's triangle and the TPACK conceptual framework in teacher training, using it fully to guide the development and promotion of teacher training courses regarding the insertion of teaching technologies in a pedagogical way to teach chemistry in its different dimensions.
Keywords	chemical education, ICT, Brazil, teachers, TPACK, model

INTRODUCTION

As a consequence of the COVID-19 pandemic, drastic changes have occurred in teaching and learning. It has affected almost all aspects of the educational context and impacted all levels of education (Sahlberg, 2021). It brought with it a need to better understand the role of technologies and its human connections within the educational system which was not designed to promote remote teaching and, apparently, demonstrated that learning has been carried out in a space composed basically of a triad founded by teacher, students, and activities (Cleophas & Bedin, 2022; Silva et al., 2021). That is, there is a historical and specific design of the teaching and learning process in which the teacher holds the knowledge and, through activities, tries to pass it on to the students, above all, without direct or indirect relation to their context. While it is understood that the educational space is not easily moldable, during COVID-19 educators needed to adapt quickly and adopt new approaches. In many cases, emergency remote learning was implemented quickly as a way to try to mitigate the negative and still immeasurable impacts on student learning where learning could no longer happen face-to-face (Bedin & Cleophas, 2022; Sutton & Jorge, 2020).

In 2005, a conceptual framework was developed to propose the integration of technology with a focus on improving teaching and learning processes. This structure became known as Technological Pedagogical Content Knowledge (TPACK) (Koehler & Mishra, 2005), with the role of guiding the teacher's knowledge (Engida, 2014) in the integration of three domains of knowledge during a given instruction; that is, Technological Knowledge (CT), Pedagogical Knowledge (PC) and Content Knowledge (CK) (Koehler & Mishra, 2008). The intersections among these basic sets of knowledge domains give rise to four other different domains, the central intersection being called TPACK knowledge (Ribeiro & Piedade, 2021).

According to Koehler and Mishra (2009), to offer meaningful and highly proficient teaching, it is necessary that the simultaneous integration of each domain of knowledge occurs. After all, TPACK guides the teacher about the pedagogical insertion of digital technologies in the classroom with a view to scientific content, and not just about their operation and handling. It is the basis of knowledge about the complex multimodalities' relationships between pedagogy, content, and technology (Silva et al., 2021).

Nevertheless, the possibility should be considered that, at any time, the conceptual structure of the TPACK model may be expanded, essentially in its different types of integrated components, like the context, the formation, self-efficacy, and teaching beliefs, research objectives, and objects, experiences and knowledge, the students, resources, and school conjecture, to make it more explicit and operational. Therefore, as Soza (2020, p. 141) explains, it is necessary to pay attention to the implications of integrating technologies in teacher training beyond TPACK, presupposing "elements of the context related to the organization and structure of the institution, available resources, curriculum, educational actors, experiences, attitudes, and feelings, as well as the methodological and conceptual transformations."

In view of the above, the objective of this article is threefold. It aims to: (i) investigate how a group of subjects see the relationship between the integration of content, pedagogical and technological knowledge of their chemistry teachers in the light of the teaching practices developed during the pandemic to the analysis of the conceptual structure of Pedagogical Technological Content Knowledge (TPACK); (ii) illustrate a model aimed at teaching chemistry teachers based on the TPACK conceptual framework and Johnstone's Triangle; and (iii) integrate empirical research on teachers' relationship with technology in the remote classroom during the pandemic.

THEORETICAL FOUNDATION

It is known that there are several challenges involved in science education in the 21st century, such as social, cultural, economic, political, and pedagogical issues, that influence the methodological instruction of teachers and students (McFarlane, 2013). In this route, promoting the integration of Information and Communication Technologies (ICT) in chemistry teaching is still a complex topic when it comes to teachers (in practice and those still in training) since the planned insertion of classroom technologies is often discredited in the teaching and learning processes.

Indeed, student learning depends on the pedagogical approaches that teachers use in the classroom (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2018), although it is also known that the development of an effective pedagogy derives from several factors, such as teachers' strategies and resources in the progress of their classes, the interest of the students, and the available infrastructure. However, technology is increasingly gaining a prominent role in educational contexts. Especially after the COVID-19 pandemic, the existing relationship between technology and teacher has proved to be indispensable. UNESCO has been alerting for a long time to the importance of educational technologies, since it considers that, when inserted in the school environment, it should be seen as a systematic method to create, apply and define all educational and teaching processes that consider technical and human resources, in addition to their interaction. Nonetheless, it is necessary to consider that the articulation of ICT with educational practices initially depends on a personal decision (Costa et al., 2012).

Chemistry is an abstract science (Jong & Taber, 2007) and with regard to its teaching, the presence of representational levels during pedagogical instruction in the classroom is indispensable for full understanding. Johnstone (1991) proposed three representational levels for chemical science, making up the vertices of a triangle, considering the macroscopic, submicroscopic, and symbolic worlds, stating that the student must move shrewdly through them to demonstrate an expressive understanding of science and create models of explanation. The transition through these levels evidences a student's broad empirical knowledge since it requires cognitive agility between reading and interpreting a phenomenon to explain it scientifically through the representation of a model.

At the macroscopic level, the phenomenon is observed from its properties, emphasizing the student's context, given that it corresponds to observable and perceptible chemical processes in a visible dimension (Pauletti et al., 2014, p. 124). At the submicroscopic level, from specific models, the properties of chemical systems are explained based on the arrangements of your constituents (ions, atoms, and molecules). Finally, at the symbolic level, equations, codes, and symbols mathematically represent the phenomenon, both at the macroscopic and submicroscopic levels.

Like TPACK, Johnstone's triangle also acts as a pedagogical framework to guide teaching and learning and, when geared to the chemical universe, provides clear guidelines for everyone involved in chemical education (Reid, 2021). While experienced chemical teachers can fluently move between these representational levels of chemical knowledge, students, on the other hand, need help (Mahaffy, 2006; Schmidt, 2021; Taber, 2013; Talanquer, 2011). Both the model proposed by Johnstone (Figure 1A) and the conceptual structure that integrates TPACK, developed from Shulman's (1986) studies on Pedagogical Content Knowledge (Figure 1B), generate improvements in learning and student performance, in addition to guiding teaching actions during the elaboration of pedagogical instructions.

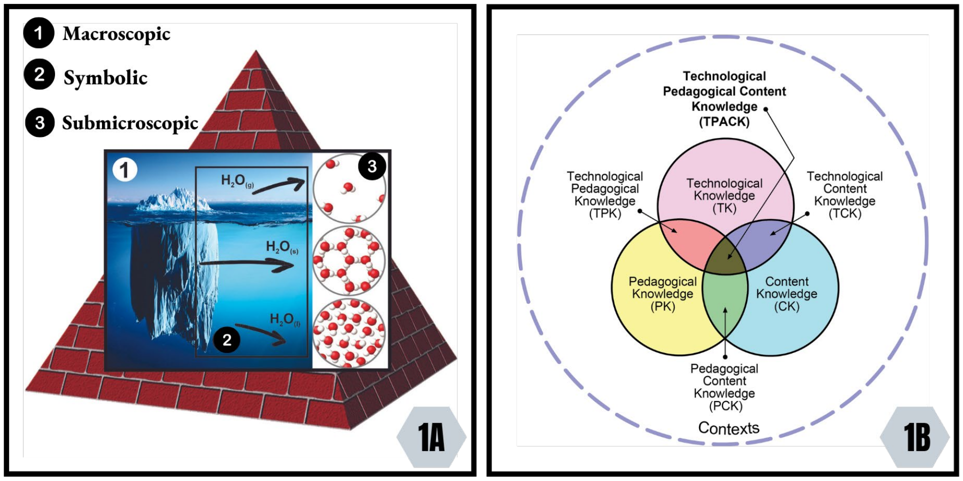


Figure 1. (A) Adaptation of the Johnstone triangle (Johnstone, 1982, 1991). (B) TPACK model based on http://www.tpack.org/

In view of this and considering the specificities of each model as well as their pedagogical intentions, it is possible to propose a fusion of them aiming at the integration of multilevel thinking in the teaching and learning processes of chemistry (Johnstone, 1991) in the light of TPACK. That is, inserting technology in a pedagogical way to develop scientific content in a chemical unit that considers the macroscopic, symbolic, and microscopic levels before the explanation of chemical phenomena, in order to increase the students' cognitive activity and the effectiveness of the learning process, becomes highly relevant and necessary (Sadykov & Čtrnáctová, 2019). Engida (2014) clarifies that TPACK is not a professional development model; it is a foundational structure for the teacher's knowledge which may be connected with the crucial representational levels for chemistry to be taught effectively, for example, by demonstrating to students its relevance to humanity, promoting interest, curiosity, and understanding about the vital concepts for their learning (Cardellini, 2012).

Figure 2 reveals a framework of the proposed model. It was constituted from the combination of Johnstone's (1991) triangle and the TPACK conceptual framework. In this model, all the intersections between the domains that make up the TPACK structure are maintained, as well as all the subdomains that arise from the interrelation between the domains referring to the Pedagogical Technological Knowledge (PTK), the Technological Content Knowledge (TCK) and the Pedagogical Content Knowledge (PCK). It is argued that TPACK needs to be present during chemical instruction and can contain the three representational levels (macroscopic, symbolic, and submicroscopic) to favor learning about chemistry, precisely because the teacher's knowledge regarding the content, pedagogy, and technology must be aligned with the representational levels proposed by Johnstone.

Since its publication, the chemical triplet proposed by Johnstone (1991) has been heavily reviewed by several authors. So, discussions about it are not watertight (Mahaffy, 2006; Taber, 2013). The macroscopic, submicroscopic, and symbolic levels are inserted with the other TPACK model intersections, making chemistry contents more flexible. This allows the teacher to move through the TPACK domains of knowledge, recognizing that macroscopic, submicroscopic, and symbolic level ideas must be intertwined with the effective use of the TPACK structure in order to promote the teaching which enhances students' learning: an effective pedagogy generating authenticity for the students and helping them improve their learning experiences in chemistry (Mishra & Koehler, 2006).

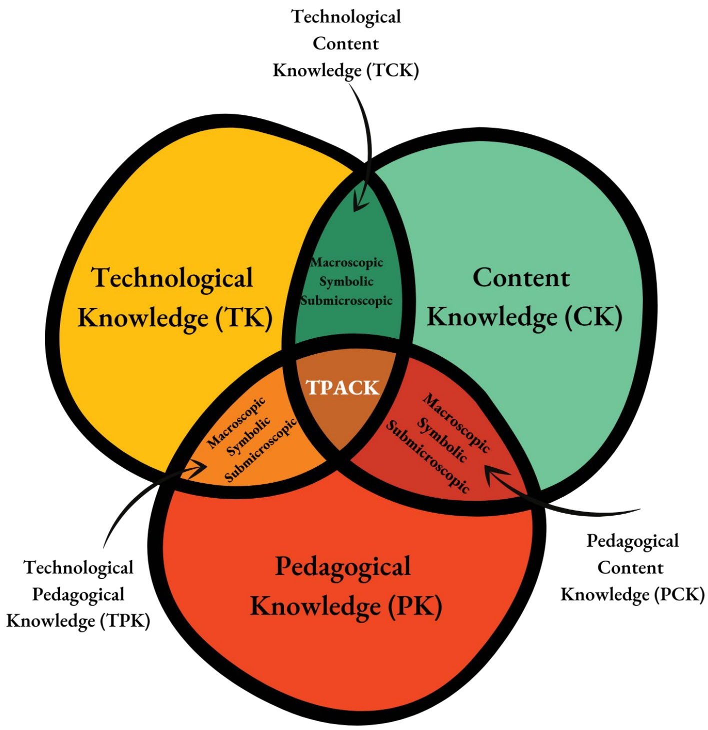


Figure 2. Integration between TPACK and Johnstone's (1991) triangle

Still on the proposition of a model aimed at chemical instruction, the notes of Maeng et al. (2013) were also adopted, considering that to be more effective. Educational technologies must be located in a flexible structure of content and pedagogy knowledge, as teaching chemistry effectively requires an understanding of its conceptual foundations as well as various strategies to overcome difficulties (Boesdorfer, 2019). Proof of this has been observed during the COVID-19 pandemic, given that it has impacted the teaching methods, implying the adoption of technologies on teaching and student learning (Babinčáková & Bernard, 2020; Canal et al., 2021; Mojica & Upmacis, 2022; Shidiq et al., 2021; Wijenayaka & Iqbal, 2021).

After all, it is understood that the teaching of chemistry should serve not only to constitute in the subject a scientific learning, shaped from the assumptions of Scientific Literacy and Technological Literacy but in the perspective of enabling the student with sufficiently human conditions so that the student can know and understand reality and himself/herself (Bedin, 2021). In view of the above, it is argued that in the proposed model it is possible to integrate technologies in teaching chemistry by considering its macroscopic, submicroscopic, and symbolic levels according to the specificity of the contents, although the conceptual understanding of chemistry ends up being provided most of the time through the submicroscopic and symbolic levels (Tsaparlis, 2009).

In the educational field, the successful integration of technology in chemistry teaching is directly related to flexibility to move through the fields of scientific, pedagogical, and technological knowledge. The integration of Johnstone's (1991) model in the classroom is directly linked to the teachers' knowledge, to their didactics, and in this context, to the employ of analogies and everyday examples to improve students' understanding of chemistry. In this way, the macroscopic level can be characterized as visible chemistry in which changes in the properties of matter can be described directly through the senses (e.g., changes in state, color, temperature density, and flammability), while the submicroscopic level is associated with the behavior of nanometric units such as atoms, ions, and molecules. The symbolic level, on the other hand, refers to the representation of macroscopic and submicroscopic phenomena, symbolically using mathematical and chemical equations, molecule formulas, diagrams, and so forth (Schmidt, 2021). Thus, the triangle representing the levels of description in chemistry helps to recognize the hindrances students have in learning, explaining macroscopic phenomena at a submicroscopic level (Abels et al., 2020), endorsing that there is a robust relationship between the TPACK theoretical model and the Representational Levels of Chemistry, since for the student to move through the different levels, the teacher's ability and competence is salutary.

Furthermore, while Pedagogical Technological Knowledge is central for the student to understand the macroscopic world of chemistry at a higher cognitive level (since in this field the teacher needs to demonstrate, through technology and pedagogy, the chemical world around the student, based on elements from their own daily lives), the Technological Knowledge of the Content is primordial for guiding the student's transition from the macroscopic level to the submicroscopic level, instigating the subject via appropriate (and chemical) software which emphasize, for example, the quantum nature of matter. Finally, to represent chemistry meaningfully through formulas, codes, and symbols, teachers need to master Pedagogical Content Knowledge to pedagogically teach the use of representational elements and mathematical calculations to describe a chemical reaction.

Apparently, the most complex level of integrating technology is the macroscopic level when referring to its experimental context. However, a study by Spyridon and Tsaparlis (2013) revealed that including simulations before a lab activity has become an effective way to improve problem-solving ability. The pivotal role of this level has as a priority the laboratory work whose purpose is to allow the adequate observation of the phenomena by the students. Although, it is quite common for students to fail while recording all observations as well as working memory overload (Tsaparlis, 2009). In order to resolve such problems, the use of technologies to support instruction at the macroscopic level has advantages for the educational context by reducing the costs of a safe and well-stocked chemistry laboratory. To this extent, technology is extremely versatile in chemistry, and it should not be excluded from the chemistry teaching process, as it has the potential to fill gaps in the development of laboratory skills (Achuthan et al., 2021). It is possible to use simulations, videos, mobile applications, games, social networks, software, and platforms, in addition to emerging technologies such as robotics, virtual, augmented, and mixed reality, among others.

RESEARCH METHOD

The research presented here fits into a study with a quantitative approach with a deductive bias, using a set of different statistical methods to constitute a standard of analysis, given the broad scope established.

PARTICIPANTS

Participated in this research, voluntarily, 324 students of higher education courses in Chemistry in institutions of public education, in the modality of bachelor and licentiate, from the five regions that make up the Brazilian territory.

PROCEDURES FOR DATA COLLECTION AND VALIDATION

In this field, the instrument for the construction of data was a questionnaire on the Google Forms platform, composed of two sections. In the first section, it was sought to probe the profile of the participants, considering the age group, the region of the country, the undergraduate course, and the identification of gender. The second section contained 21 assertions based on 7 levels of knowledge and distributed on a scale based on the Likert (1932) proposal, containing four scoring options ranging from lower scores (1 and 2), classified as strongly disagree and disagree, to higher scores (4 and 5) characterized as agree and strongly agree, respectively. It was chosen not to include a neutral point of the constructed scale to encourage a position on the part of the respondents (Cleophas & Cunha, 2020; Colton & Covert, 2007; Lucian, 2016).

The questionnaire was made available online through a link to different students of undergraduate chemistry courses, both licentiate and bachelor, from all over Brazil, through their course coordinators, and was in circulation for a week. For this process, by email, without any inclusion or exclusion criteria, professors and Chemistry Course Coordinators from Brazilian Universities were asked to participate by sending the online survey to their chemistry undergraduates. Therefore, it is not possible to measure the number of undergraduates reached (population). As the link to the online survey was sent by the coordinators, who had free will to select who to send it to, the response rate is unknown. Regarding the experiential educational context in which undergraduate students scored a grade for each of the 21 assertions (Table 1), it is stated that, due to the growth of infections by the SARS-COV-2 virus, it was developed entirely in a non-face-to-face manner, as the Ministry of Education (MEC; Ministério da Educação, 2020) granted Ordinance No. 343, of March 17, 2020, allowing educational institutions to develop their classes in digital media.

Table 1. Assertions used to identify TPACK in teaching practice

My teacher...
Content Knowledge - CK
(A) ... demonstrated sufficient scientific knowledge of chemistry.
(B) ... thought about the scientific contents of chemistry as an expert on the subject.
(C) ... deeply understood the scientific contents of chemistry.
Pedagogical Knowledge – PK
(D) ... was able to expand my thinking ability through challenging tasks.
(E) ... guided me to adopt appropriate learning strategies.
(F) ... was able to monitor my learning.
Pedagogical Knowledge of Content – PKC
(G) ... managed to deal with the most common misconceptions I had.
(H) ... addressed different teaching strategies to guide me in thinking and learning chemistry.
(I) ... managed, in different ways, to help me understand chemical knowledge.
Technological Knowledge – TK
(J) ... presented effective technical skills when using technologies in remote teaching.
(K) ... knew how to solve technical problems related to technology during remote teaching.
(L) ... used various internet tools and social media in his classes.
Pedagogical Technological Knowledge – PTK
(M) ... was able to use technology to insert myself into real-world situations.
(N) ... helped me to use technology and get data, plan and verify my learning.
(O) ... helped me use technology to build different forms of knowledge representation and to work collaboratively.
Technological Knowledge of Content – TKC
(P) ... used computer programs and software created for chemistry in his classes.
(Q) ... demonstrated knowing how to use technology to research chemistry.
(R) ... used different technologies to represent chemistry content in their classes.
Pedagogical Technological Knowledge of Content – PTKC
(S) ... taught classes combining technology, chemical content, and teaching strategies.
(T) ... with technology, enriched the classes and facilitated my learning in chemistry.
(U) ... showed technological knowledge, teaching strategies, and chemical knowledge.

That said, it is stated that from the second section of the questionnaire, the 21 assertions were used (Table 1) that were separated into named categories of factors, thus constituting a set composed of 3 factors (Table 3), namely: Factor 1: Field of Knowledge mostly Technological; Factor 2: Field of Knowledge mostly Pedagogical; and Factor 3: Field of Knowledge mostly Scientific. Furthermore, it should be noted that the data present in the Google Forms platform was downloaded into an Excel spreadsheet, considering ordinal data, to perform the analysis in Python (Millman & Aivazis, 2011), via pandas packages (McKinney, 2010), Matplotlib (Hunter, 2007) and Seaborn (Waskom et al., 2017), summarizing the data in tables and figures.

Analysis Procedures

Based on the profile of the research participants, and considering that it is heterogeneous in all dimensions, the Internal Consistency analysis was carried out through the calculation of Cronbach's (1951) Alpha Coefficient and the corrected item-total correlation coefficients for all items in the questionnaire. The maximum value of Cronbach's alpha is equal to the unity. Here it was calculated both globally (analyzing the entire construct) and after the elimination of each item, to assess its dependence on each item of the questionnaire. Values above 0.70 (Cortina, 1993) are indicative of good internal consistency for the use of the scale in the comparison between groups, whereas values greater than 0.90 are necessary for the use of the scale in the comparison between individuals. Additionally, the corrected item-total correlation coefficient quantifies the relationship between the item and the questionnaire's total score, with values between +1 and -1 (Zijlmans et al., 2019). Such quantities are shown in Table 2.

Table 2. Analysis of Cronbach's Alpha and the correlations between the assertions

Item	Cronbach's Alpha eliminating the item	Corrected total item correlation	Item	Cronbach's Alpha eliminating the item	Corrected total item correlation	Item	Cronbach's Alpha eliminating the item	Corrected total item correlation
A	0.947	0.314	**H**	0.943	0.719	**O**	0.943	0.753
B	0.948	0.287	**I**	0.943	0.705	**P**	0.945	0.597
C	0.947	0.322	**J**	0.944	0.672	**Q**	0.944	0.674
D	0.944	0.608	**K**	0.944	0.622	**R**	0.942	0.762
E	0.945	0.587	**L**	0.944	0.694	**S**	0.942	0.808
F	0.944	0.639	**M**	0.943	0.702	**T**	0.942	0.765
G	0.945	0.579	**N**	0.942	0.773	**U**	0.943	0.742
Cronbach's Alpha of the entire questionnaire: 0.947								

After evidencing the invariability of Cronbach's Alpha Coefficient (greater than 0.90) by eliminating each of the statements, the Exploratory Factor Analysis of the questionnaire was carried out to understand the best way to group its various items in the latent variables, thus impelling evidence for its validity. As the number of research participants was higher than recommended (300 subjects), combined with the fact that the ratio between the number of participants and the number of Likert items was greater than 15:1, greater than the recommended minimum ratio of 10:1 (Costello & Osborne, 2005), the analysis proved to be appropriate. Next, Bartlett's Sphericity test was performed to verify a possible correlation between the observed variables, using the comparison between the correlation matrix and the identity matrix. As a result [$X^2 = 5393$, $p = 0$], Bartlett's test presented a p-value equal to zero, indicating that the sample was statistically significant, that is, the observed correlation matrix differs from the identity matrix.

The following analysis took place through the application of the Kaiser-Meyer-Olkin (KMO) criterion, also known as the sample adequacy test, which analyzes whether the data set is capable of factoring. The result represents the degree to which each of the observed variables can be predicted, without error, by the other variables in the data set. After all, the KMO is an estimate of the proportion of variance between all variables, where the values are between 0 and 1; a value less than 0.60 is considered inappropriate. Thus, as shown in Table 3, the Global Value of KMO was 0.947.

Table 3. Analysis of the Kaiser-Meyer-Olkin criterion for each assertion

Item	KMO Value	Item	KMO Value	Item	KMO Value
A	0.868	**H**	0.950	**O**	0.937
B	0.864	**I**	0.940	**P**	0.961
C	0.837	**J**	0.932	**Q**	0.954
D	0.963	**K**	0.919	**R**	0.960
E	0.933	**L**	0.964	**S**	0.966
F	0.939	**M**	0.976	**T**	0.969
G	0.955	**N**	0.945	**U**	0.968

Considering that the values shown in Table 3 were above 0.80, the Exploratory Factor Analysis was carried out in *Python* (Persson & Khojasteh, 2021), using principal axis factoring as a factor extraction method, since the data showed a non-normal distribution by the Shapiro-Wilk test (Shapiro & Wilk, 1965). The rotation method chosen was the oblique rotation method, 'promax', as this allows the factors to be correlated. The choice of the number of factors can be performed using the Kaiser criterion or the slope graph, both based on eigenvalues. Using the calculated eigenvalues, a *Screeplot* was plotted, a graph that lists the eigenvalues in descending order, used to determine the number of factors to be retained in an exploratory factor analysis. The test, introduced by Cattell (1966), suggests keeping as many factors as there are eigenvalues before a "sharp bend" or "elbow" in the graph.

RESULTS

In Figure 3, the relationship between gender, age group, undergraduate course, and region of the country of research participants is presented.

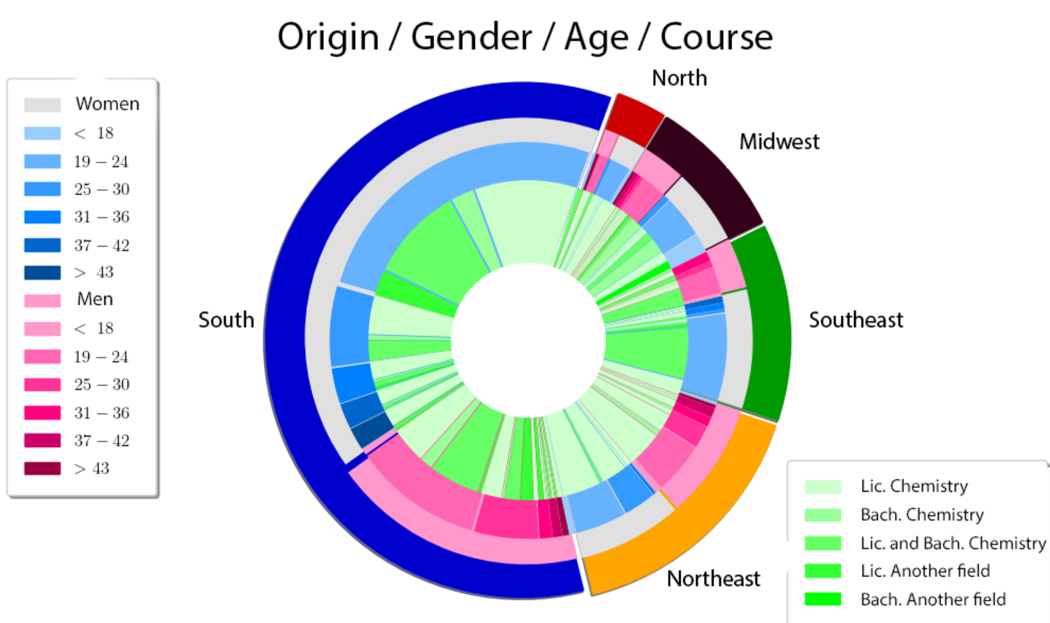


Figure 3. Relationship between the categories that expose the profile of the subjects

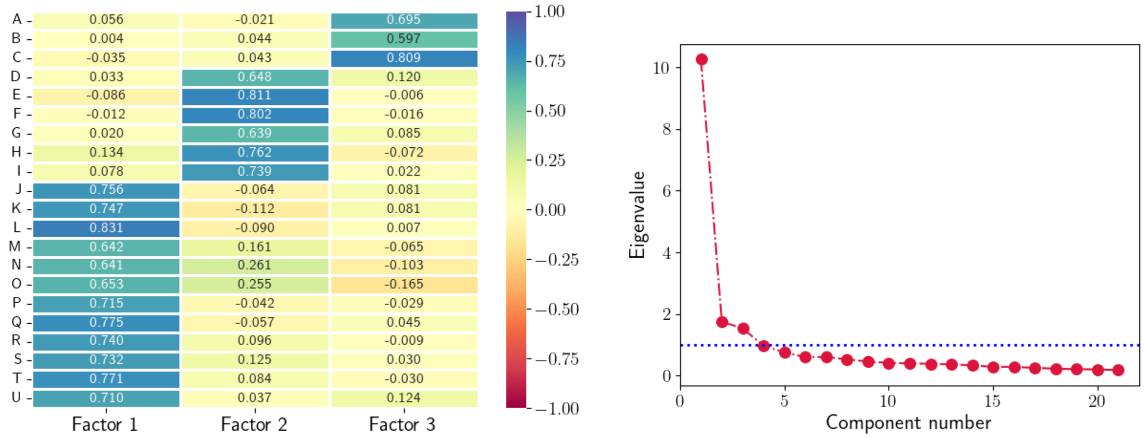
It is worth noting that Brazil is a continental country divided into five geographical regions: North, Northeast, Midwest, Southeast, and South. In summary, from Figure 3, it can be seen that 5.5% (n = 21) of the respondents are aged less than or equal to 18 years, with the majority (n = 8) from the southern region of the country and the feminine gender (n = 15). Subjects aged between 19 and 24 years comprise the highest percentage of the group (61.7%, n = 234), with the majority from the South region (n = 137) and females (n = 158). No different, females (n = 39) and the southern region of the country (n = 45) include subjects aged between 25 and 30 years (18.3%, n = 69). The southern region of the country also appears with the largest number of respondents for subjects aged between 31 and 36 years (6.6%, n = 25) and also for those aged between 37 and 42 years (4.7 %, n = 18), with females comprising the largest group (n = 14; n = 10, respectively). Finally, there is the group of subjects aged 43 years or older, which is represented by 3.2% (n = 12) of the group, 5 males (1 from the North region, 1 from the Northeast region, 1 from the Midwest region and 2 from the South region) and 7 females (South region). The south region of Brazil is the third most populated region in Brazil; therefore this is why it has the highest number of respondents. However, another possible reason for its higher representation in this study was that two (of the three) researchers in this study come from institutions located in the South, therefore potentially having a greater influence on the engagement of the respondents. All data are presented in Table 4.

Table 4. Distribution of survey participants by region, sex, and age

	Subgroups	**Number of respondents**
Sex	Female	243
	Male	133
	Other	3
Age	< 18	21
	19 to 24	234
	25 to 30	69
	31 to 36	25
	37 to 42	18
	> 43	12
Region	Midwest	34
	Northeast	61
	North	12
	Southeast	47
	South	225

From the heat map with factor loadings and the slope graph (Figure 4), the items were divided into three factors, which explain 54.66% of the total variance.

Based on what is shown in Figure 4, Table 5 was plotted, in which the three factors and the corresponding items of the instrument are presented. It is noteworthy that Factor 1 presents the Content Knowledge (CK), while Factor 2 presents assertions related to Didactics, with assertions D, E, and F intended for Pedagogical Knowledge (PK) and assertions G, H, and I refer to Pedagogical Content Knowledge (PCK). Accordingly, Factor 3 is related to the use of technologies, considering that assertions J, K, and L deal with Technological Knowledge (TK), assertions M, N, and O of Pedagogical Technological Knowledge (PTK), the assertions P, Q, and R of the Technological Content Knowledge (TCK) and the assertions S, T, and U of the Pedagogical Technological Knowledge of the Content (PTKC).



(a) **(b)**

Figure 4. (a) Heat map with factorial categories; (b) Slope graph

Table 5. Questionnaire factors and items

Items related to the statement: MY TEACHER ...	**Load**
Factor 1: Field of Knowledge mostly Scientific	**F1**
A: ... demonstrated sufficient scientific knowledge of chemistry.	**0.695**
B: ... thought about the scientific contents of chemistry as an expert on the subject.	**0.597**
C: ... deeply understood the scientific contents of chemistry.	**0.809**
Factor 2: Field of Knowledge mostly Pedagogical	**F2**
D: ... was able to expand my thinking ability through challenging tasks.	**0.648**
E: ... guided me to adopt appropriate learning strategies.	**0.811**
F: ... was able to monitor my learning.	**0.802**
G: ... managed to deal with the most common misconceptions I had.	**0.639**
H: ... addressed different teaching strategies to guide me in thinking and learning chemistry.	**0.762**
I: ... managed, in different ways, to help me understand chemical knowledge.	**0.739**
Factor 3: Mostly Technological Field of Knowledge	**F3**
J: … showed effective technical skills when using technologies in remote teaching.	**0.756**
K: … knew how to solve technical problems related to technology during remote teaching.	**0.747**
L: … proved able to use various internet tools and social media in his classes.	**0.831**
M: … was able to use technology to insert myself into real-world situations.	**0.642**
N: … helped me use technology to gather information, plan and verify my learning.	**0.641**
O: … helped me use technology to build different forms of knowledge representation and work collaboratively.	**0.653**
P: … managed to use computer programs and software created for chemistry in his classes.	**0.715**
Q: … demonstrated knowing how to use technology to research chemistry.	**0.775**
R: … used different technologies to represent chemistry content in their classes.	**0.740**
S: … taught class combining technology, scientific chemistry content and teaching strategies.	**0.732**
T: … with technology, enriched his classes and facilitated my learning in chemistry.	**0.771**
U: … demonstrated technological knowledge, teaching strategies and chemical knowledge.	**0.710**

Based on the data presented in Table 5, the values were measured using the Commonality, which is characterized by the sum of the squared factor loadings of each measured variable and it serves to evaluate the performance of the model: the greater the commonality, the greater the explanatory power of that variable by the factor. The total commonality of the assertions is 11.4797 which, divided among the 21 variables, indicates an average of 0.5466; that is, an average efficiency of around 54.66% of the model in explaining the variation of each variable in the test. Based on the data, it was decided to carry out an analysis of the internal consistency of the factors and possible differences between them, which was measured using Cronbach's alpha coefficient. According to Table 6, it can be seen that the three factors had alpha coefficient values above satisfactory (0.70).

Table 6. Factor analysis from Cronbach's Alpha

Factor	Cronbach's Alpha	Mean	Standard Deviation
F1	0.944	2.639	0.974
F2	0.893	2.762	0.973
F3	0.747	3.598	0.606
Complete questionnaire	0.947	2.811	0.985

To analyze the differences in the mean scores, the non-parametric Kruskal-Wallis test (Kruskal & Wallis, 1952) was used since the mean scores showed non-normal behavior by the Shapiro-Wilk test. Furthermore, Dunn's (1964) post hoc test was used to understand the differences between each pair of factors adopted in the research. The mean scores of the different factors were all significantly different at a significance level of 99%, while statistically significant differences were found between the mean scores of the pairs of Factors 1 and 3 ($p = 0.00$) and 2 and 3 ($p = 0.00$), with no significant difference between Factors 1 and 2 ($p = 0.11$). These results indicate that, globally, Factor 3 has the highest mean score, suggesting that respondents were more likely to agree with assertions related to the area of knowledge specifically linked to science, corresponding to Content Knowledge, thus revealing something quite healthy, when it is thought that mastering the content of the discipline that is taught is a necessary action to be able to develop the teaching process. Factor 2, corresponding to the mostly pedagogical field of knowledge, had the second highest average score, while the first factor, characterized by the field of knowledge that requires technological knowledge, from Technological Knowledge to Pedagogical Technological Knowledge of Content, was in the last position, with a value lower, including the general mean of the instrument.

The average level of agreement per factor is shown in Figure 5, and it is possible to highlight an average percentage of positive self-perception (which encompasses the options "agree" and "strongly agree") decreasing towards Factor 3 (~95%) > Factor 2 (~62%) > Factor 1 (~56%). In this support, based on the data, the differences between the average scores for the different groups are presented in detail in Table 8.

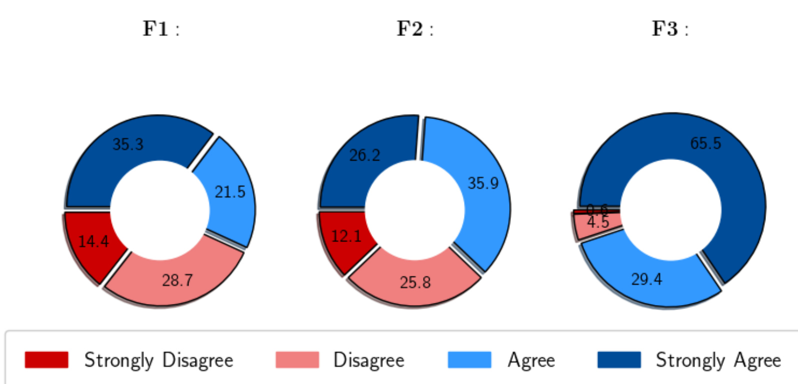


Figure 5. Average agreement by factor

Table 8. Average scores by category

Categorical Variables										
	Gender				Age					
	M	F		O	≤18	19-24	25-30	31-36	37-42	>43
F1	2.646	2.637		2.528	2.53	2.56	2.56	2.91	2.88	2.80
F2	2.763	2.758		2.944	2.37	2.60	2.64	2.92	2.89	3.01
F3	3.598	3.595		3.777	2.49	2.85	2.92	3.14	3.14	3.30
	Region					Teacher Education				
	N	NE	MW	SE	S	LC	BC	LBC	LO	BO
F1	2.36	2.51	2.51	2.63	2.65	2.57	2.53	2.68	2.33	2.70
F2	2.34	2.48	2.60	2.65	2.71	2.55	2.58	2.73	2.59	2.92
F3	2.33	2.52	2.83	2.94	3.01	2.62	2.96	2.93	2.78	3.13
	Graduation Course					Graduation period				
	LC	BC	LBC	LO	BO	1-2	3-4	5-6	7-8	9-10
F1	2.54	2.62	2.70	2.72	2.22	2.64	2.51	2.58	2.60	2.74
F2	2.57	2.67	2.74	2.83	2.33	2.56	2.58	2.64	2.76	2.82
F3	2.75	2.91	3.03	3.31	3.00	2.69	2.85	2.91	3.00	3.21

Given the data presented in Table 8, it should be noted that the differences between the mean scores of the instrument were examined using the Kruskall-Wallis test for all categorical variables (Gender, Age, Region, Teacher Training, Undergraduate and Graduation period) since they have more than three "subdivisions".

DISCUSSION

In this field, calling the average score obtained by a certain categorical variable as Level of Agreement, the results attest that, with regard to Factor 3, characterized by the predominantly Technological Field of Knowledge, and with a significance level of 95%, there are no statistically significant differences between the variables: i) Gender and Level of Agreement; ii) Region and Level of Agreement; and iii) Graduation Period and Level of Agreement. Thus, it can be seen that there are statistically significant differences for the variables Age, Course, and Teacher Education (the latter for a significance level of 90%), when compared with the Level of Agreement, indicating that the differences observed in the mean scores of Table 6, for these three categorical variables, are not the result of chance. Thus, for these three variables (which were statistically different), Dunn's post hoc test was carried out, to determine the differences between the Level of Agreement and each of the subdivisions of the three categorical variables mentioned above, taken twice to two. For the Age variable, through Dunn's test, statistically significant differences can be seen between the age groups 19 to 24 years and 31 to 36 years, as well as between 25 to 30 years and 31 to 36 years. For the other two variables (Teacher Training and Undergraduate Course), no significant differences were found between the variables when taken two by two, demonstrating that the scores of the two variables had no direct significant effects on the mostly Technological Field of Knowledge.

In this bias, it is possible to affirm that subjects aged between 31 and 36 years old differ statistically from those with younger age, indicating that Factor 1 exerts a significant influence on the degrees of agreement for subjects in this age group. This design may be a derivation that subjects aged between 31 and 36 are not part of the so-called "digital natives," which means saying that, perhaps, for them there is no transformation in the way the teacher presents or not skills and competences when using technologies in remote teaching, as well as solving or not solving technical problems of a technological nature, among others, using or not using different internet tools and social media during classes. Apparently, these subjects care more about the learning process, which can be related only to scientific and pedagogical activities, than about the specific path during the process. In other words, it is understood that Factor 1, as it presents a predominantly Technological Field of Knowledge, presents a distinction in the degrees of agreement between subjects born in different decades. This corroborates the ideas of Soong and Tan (2010) because, for these students, the teacher must be able to transmit the information known correctly and at the right time; that is, the content of the correct material through the use of good pedagogical activities, regardless of the use of technologies.

Furthermore, it can be inferred that subjects aged between 31 and 36 years are those who are in an advanced period of the undergraduate course, in relation to the others, which means that, regardless of the use of technologies in the pandemic period for pedagogically stimulating learning and the insertion of subjects in the world of chemistry, their teachers were able to demonstrate scientific knowledge in a macroscopic, symbolic, and submicroscopic way. Perhaps this process occurs frequently in the physical laboratories of universities, which characterized the thinking of the subjects in congruence with the teaching actions, even if these did not occur during the pandemic period, thus statistically differentiating the thinking of subjects aged between 31 and 36 years old, who have already experienced face-to-face actions with their teachers, from those aged between 19 and 30, who possibly started their graduation at the beginning of the pandemic.

In line with this, studies conducted by Bedin and Cleophas (2022) reveal that the age group of subjects has a statistically significant influence on the field of technological knowledge, essentially in relation to the skills and competencies of their teachers in the act of teaching. The findings reveal that younger students have different perceptions than older students regarding their teachers' ability to appropriate technology to use software created for chemistry in their classes, and also to build different ways of representing knowledge and working collaboratively. Carlini (2008) justifies this design by stating that teachers have become attached to the process of transmitting knowledge, and the insertion of technological tools in higher education, for example, requires the teacher has a continuous need to adapt in their daily activities, which has hindered the appropriation and use of technologies by teacher educators.

Analyzing Factor 2, fundamentally comprising the predominantly Pedagogical Field of Knowledge, it can be seen that, except for the variable Gender, the other variables showed statistically significant differences when their mean scores were compared. Below, provisional interpretations are given that would need to be tested in future studies, given that, when Dunn's test was applied to each of these categorical variables, it was briefly obtained.

i) **Age:** it was possible to notice that younger people (mainly those still in their teens - up to 18 years old) tend to present a much lower agreement than older students regarding the understanding of the pedagogical actions of teachers being able to make subjects expand their understandings and, among other processes, learn through different biases. This finding may derive from the idea that younger subjects are able, through time and through cognitive and motor skills, to individually expand their learning horizons, managing to deal with their own mistakes and, among other pedagogical actions, to think and learn chemistry in a different multilevel way.

ii) **Region:** statistically significant differences were found between the average scores of the North and Northeast regions when compared to the average scores of the South region, showing a difference in understanding of the teacher's pedagogical skills. This assertion may be linked to issues of infrastructure and didactic conditions, as well as human resources present in the departments of the different universities. After all, historically, in Brazil, the North and Northeast regions face different difficulties with regard to the teaching of chemistry; such as, for example, lack of access to technologies, shortage of qualified teaching workforce, and scientific resources for understanding science chemistry at the macroscopic and submicroscopic levels.

iii) **Teacher Training:** statistically significant differences were observed between the mean scores of students who believe that their teachers have a Licentiate degree in Chemistry with those who think that their teachers have a Licentiate degree and a Bachelor's degree in Chemistry and with those who believe that their teachers have a Bachelor's degree in another area. In addition, distinctions were noticed between the mean scores of students who recognize that their teachers have a Bachelor's degree in Chemistry with those who believe that their masters have a Licentiate and a Bachelor's degree in Chemistry, indicating that teacher training implies the pedagogical actions of the teacher. This investigation is directly related to the scientific-pedagogical action of the teacher, especially because Factor 2 considers the Field of Knowledge mostly Pedagogical. In other words, subjects who believe that their teachers have a Licentiate's degree differ from those who believe that teachers have a Bachelor's degree through didactic action during the pandemic, while the perception of those who tile the training of their teachers as Licentiates and Bachelors derives from a strongly linked pedagogical action to a specific knowledge of scientific knowledge.

iv) **Graduation Course:** statistically significant differences were observed between the average scores of the Licentiate in Chemistry students in relation to the Licentiate and Bachelor of Chemistry students, and of the Licentiate students in another area, indicating that the teacher's pedagogical practice is understood differently depending on the student course. This investigation can demonstrate that the students of Licentiate in Chemistry differ from those of Licentiate and Bachelor of Chemistry because they believe, perhaps, that teaching skills should extrapolate the field of scientific knowledge, looking for an expressive relationship in the pedagogical way of teaching the macroscopic world, symbolic and submicroscopic of chemistry, making it possible to measure agreement in relation to resources, and teaching actions adopted to encourage and guide subjects to think about chemistry.

v) **Graduation Period:** it was possible to find significant differences between the average means of students in the initial semesters (1st to 4th semesters) when compared to the scores obtained from students at the end of the course (8th to 10th semesters). This characteristic can be understood from two distinct but complementary moments. That is, students in the initial semesters may have started their undergraduate courses during the pandemic, which made it impossible for them to evaluate teaching actions of a pedagogical nature in their entirety. On the other hand, this falls on the students of the final semesters, who may have adopted the agreement in relation to the assertions of the Field of Pedagogical Knowledge from the experiences with their teachers before the pandemic, alluding to didactic practices not only in the pandemic.

In summary, regarding the predominantly Pedagogical Field of Knowledge, it is clear that the subjects who are at the beginning of the schooling process in Higher Education, as well as those who are part of a Bachelor's training course, present perceptions and knowledge that are different from those who are at the end of the training course and those who are doing a Licentiate course, essentially on the skills of the teacher to expand the student's thinking through challenging tasks, to guide him to adopt appropriate learning strategies and, among others, to achieve, in different ways, help him to understand chemical knowledge. This finding derives from the conception that final-year students, as well as those who are studying for a Licentiate degree, can have a more acute and grounded consideration of the pedagogical capabilities of their teachers, managing to measure more solid degrees of agreement or disagreement, whether from living with teachers at different times and in different disciplines (Age and Period of the Course) or through in-depth studies on theories that support pedagogical and curricular knowledge (Teacher Training and Course). However, these students are unaware that the quality of teaching does not depend only on the mastery of content knowledge that teachers have since it is necessary to consider fundamental aspects in teaching practice, such as questions about learning styles and assessment (Saraguro, 2020).

Still, in common with the findings in the research of Cleophas and Bedin (2022), it can be stated that the mostly pedagogical field exerts influence on the subjects' conception as to age and period in the course, indicating a failure in the teacher's pedagogical ability in the sense of provoking and monitoring student learning, perhaps by the cultural distance of age or by cognitive maturation due to the time in the course. The research of Silva et al. (2021) adds to this by demonstrating that, depending on the training course, the subjects diverge in relation to elements in the pedagogical field, specifically regarding the ability of the teacher to use different strategies and tools that facilitate learning and stimulate students to collaborate.

Furthermore, in relation to Factor 1, referring to the mostly Scientific Field of Knowledge, it is retained that this was the only one to present statistically significant differences in all categorical variables (Gender, Age, Region, Teacher Training, Course, and Period). We launch provisional interpretations below, however, it is quite pertinent that they can be tested in future studies. Thus, performing Dunn's test, the following conclusions were reached:

i) **Gender:** There were statistically significant differences between men and women, indicating that women tend to agree more with the idea that the professor has demonstrated significant mastery of the scientific knowledge being taught. This finding can reveal beliefs about the source of knowledge, as women can incorporate a very naive perspective (Chen, 2012) in relation to teaching. However, it should be noted that cognitive ability is supported by the concept that individuals operate certain types of information and, therefore, they differ cognitively because they exhibit abilities to a different degree (Marañón, 2014).

ii) **Age:** There was a great distinction between the level of agreement obtained by younger students when compared to more experienced students, in the age group over 37 years. This investigation may be related to the older subjects' ability to concentrate, as well as their experience in relation to the objects of knowledge of chemical science, given the time of studies in the course, facilitating their understanding of the macroscopic, symbolic, and submicroscopic worlds of science, when presented scientifically by the teacher.

iii) **Region:** There were statistically significant differences between the average scores obtained by students from the North and Northeast regions (which showed a lower level of agreement) when compared to those from the Midwest, Southeast and South regions, in addition to differences between the Midwest and South regions, where it was understood that the teacher thought and mastered the chemistry content like an expert. As already mentioned, the North and Northeast regions suffer from a lack of resources in relation to scientific research issues, which can even affect the maturation and updating of the scientific knowledge of professors, since a professor remains in constant improvement. There is no divergence between the South and Southeast regions because it is the Brazilian regions that, geographically, allow a greater relationship of research, allowing professors to have a scientific exchange.

iv) **Teacher Training:** The difference was significant between those students who believe that their teachers have a Licentiate degree in Chemistry when confronted with the average scores of those students who claim that their teachers have a Licentiate degree and a Bachelor's degree or a Bachelor's degree in another area, demonstrating a divergence between the conceptions of that the teacher knows and scientifically masters the chemical science. This characteristic is specific to a group of professors who do research in applied chemistry, notably those that students believe to have a Bachelor's degree, which allows them to have a greater understanding of phenomenology, be it macroscopic, symbolic, or submicroscopic, greater. This effect makes it possible, even during the pandemic, to present sufficient scientific knowledge about chemistry, as well as display a deep understanding of them.

v) **Graduation Course:** Licentiate students in another area showed a higher level of agreement than the others, and this difference was statistically significant, especially in comparison with the level obtained by Licentiate in Chemistry, Bachelor in Chemistry, and Licentiate and Bachelor of

Chemistry students. Therefore, Licentiate students in another area may have a reduced knowledge, when compared to Chemistry, Licentiate, or Bachelor students, in relation to the objects of knowledge of this science, and thus, there is disagreement regarding the agreement in the Field of Knowledge mostly Scientific. That is, a Licentiate in Physics student, for example, when having a chemistry class with a chemistry teacher, regardless of the teacher's level of abstraction, exposure, and thinking in relation to chemical science, will possibly have a perception that the teacher thinks like an expert on the subject since the teacher does not have enough knowledge about chemistry.

vi) **Graduation Period:** It was possible to perceive differences between the level of agreement obtained by students from the first semesters in relation to students from the last semesters, while no dissimilarities were observed between the average scores obtained by students in the middle of the course (3rd to 6th semesters). This finding demonstrates that end-of-course students, because they have scientific knowledge built up over the years, and matured through studies and dialogues, do not expressly agree that their teachers think as experts and have sufficient scientific knowledge about chemistry, unlike students who are starting the graduation process, since they have just arrived from high school and, possibly, their undergraduate professors have sharper scientific knowledge than their former Basic Education teachers.

In summary, when considering the predominantly Scientific Field of Knowledge, it is possible to measure that students in the final periods of graduation, and consequently with more experience (age), have a broader conception and, at the same time, more specific knowledge in relation to the conceptual content, which allows them to agree or disagree more significantly on the actions of: i) the teacher having sufficient scientific knowledge about chemistry; ii) the teacher thought about the scientific contents of chemistry as an expert on the subject; and, iii) the teacher deeply understood the scientific contents of chemistry. Not differently, Licentiate undergraduate students in another area of knowledge, different from Licentiate and Bachelor undergraduate students in Chemistry, agree that their professors master the content of the area and think about it as experts, perhaps because chemistry, being a phenomenological science, presents models and theories that can, over time and from other experiments, be improved, which makes teachers who do not constantly improve themselves feel difficulties in understanding the knowledge of their own area of knowledge.

In corroboration, it is believed that the existence of a significant difference between the subjects of the different regions of Brazil, regarding the perceptions about the competencies and teaching abilities related to the Field of Scientific Knowledge, occurs due to the low concentration of improvement courses in Chemistry for professors from the North and Northeast regions, making them present, in the evaluation of their students, knowledge that is not in-depth in relation to Chemical Science. Finally, it is judged that women, as they show more attention and organization in their studies, especially on exact sciences, agree that their teachers dominate the Chemistry content and think about it as an expert, given that when they have a greater number of connections between nerve cells in the brain, women are able to learn more easily, perhaps understanding that the derivation of this process is due to the scientific abilities and skills of their teachers. However, all provisional interpretations need to be tested in further studies; therefore, future research may also consider replicating this study, collecting information that can deeply investigate the influence of the variables adopted here.

CONCLUSION

The objective of the present investigation was to know the perception that Chemistry higher education students have about their Chemistry teachers in relation to the knowledge proposed in the TPACK model. The results allow us to conclude that, in order to promote more effective instruction by integrating technological, pedagogical, and scientific knowledge with an emphasis on macroscopic, symbolic, and submicroscopic levels, continuing education by Brazilian university professors of

Chemistry becomes necessary, especially related to the mostly Scientific Field of Knowledge (Factor 1), which showed the lowest level of agreement on the part of the interviewees.

Regarding the integration of Johnstone's triangle with the TPACK conceptual structure, it is assumed that the structuring of science under the three aspects of the triangle from the teaching domain of the TPACK structure conjectures the ease of students' cognitive appropriation in the macroscopic, submicroscopic, and symbolic embodied in the objects of chemical knowledge. Therefore, the representational character of chemical knowledge pedagogically based on digital technologies allows students to develop their imagination and create submicroscopic hypotheses and explanatory models based on the analyzed data and macroscopically observed prominences through the symbolic ability to represent specific elements of Chemical Science, using them to build meaningful knowledge.

This study has some limitations. First, the results were based only on a statistical analysis of the data, while more detailed information was not collected. For example, no individual interviews were conducted and no fine-grained analysis of the alignment or misalignment of the survey was carried out according to each participant and the scores assigned to the questionnaire. Thus, to develop a more refined understanding of chemistry students' perceptions of their professors' classes, empirical study, especially qualitative studies, in harmony with quantitative research, is highly necessary.

Second, it was not possible to survey the number of students who received the link to the questionnaire, since the Course Coordinators were contacted and sent the link to the students; therefore, there is no way to measure the research attrition rate. Third, the questionnaire made available to the research participants did not have a section of discursive questions, where qualitative and quantitative data could be crossed, demarcating the results of this study in a mixed way and with a less subjective bias. Fourth, the use of the closed questionnaire in the 21 statements referring to the TPACK is admitted as a limitation of the research, when it could be adapted by inserting statements referring to the context of the subjects, the infrastructure of the institutions, and the teaching beliefs.

Future research should, in addition to improving the proposed model that integrates the Johnstone triangle and the TPACK conceptual framework in teacher education, use elements of the subjects' context, the institutions' infrastructure, teachers' objectives and beliefs (self-efficacy and values), as well as resources, experiences, and knowledge, to make it more specific and comprehensive and consider the inclusion of open questions to elucidate components that guide the development and promotion of teacher training courses regarding the insertion of technologies in a pedagogical way to teach chemistry in its different dimensions.

In addition, given the possibility of adapting and reapplying the questionnaire, it is worth considering the progress of this research in an investigation that centralizes the perceptions of students and teachers about the concept of becoming a technological teacher in different Brazilian contexts, via scientific and didactic appropriation of technology able to outline teaching technological skills manifested after the COVID-19 pandemic in and for pedagogical practice. Still, considering the data constitution vehicle, this research can unfold in studies related to the structure of TPACK in Latin America, in an attempt to help teachers in the appropriation of technologies to link them to viable approaches in teaching chemistry.

Finally, it is necessary to develop a practical training action with a technological bias in the teaching of Chemistry, to play an instrumental role in a student's understanding process. Otherwise, it is necessary to equip undergraduate students and training teachers to be able, in an inter- and intradisciplinary way, to know the objects of knowledge of chemical science in order to improve the pedagogical and technological way of working them together.

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Faculty Perceptions of Virtual Field Experience Placement in a Teacher Preparation Program in the UAE

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Abstract

Aim/Purpose	The purpose of this study was to examine faculty perceptions of virtual field placement of preservice teachers at a university in the United Arab Emirates and to explore the factors that promote or hinder the success of this experience. Vygotsky's concept of scaffolding was used as the theoretical framework of this study and to explain the faculty's engagement with the field placement experience.
Background	The global pandemic of COVID-19 has affected the provision of teacher education programs around the world. It forced many universities to implement emergency remote teaching strategies including virtual field experiences.
Methodology	Considering the novelty of this phenomenon, an exploratory qualitative research design was followed to arrive at an in-depth description of the faculty's perceptions. A convenience sampling, which is characterized by the deliberate targeting of information-rich participants, was used to select five faculty members who supervised 40 Emirati preservice teachers during their virtual field experience. Data was collected using semi-structured interviews and analyzed using thematic analysis.
Contribution	The framework put forth in this study could serve as a guideline for teacher education programs, especially field experience preparation.

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Findings	It was found that faculty had different perceptions of virtual field experiences. Although preservice teachers were faced with unprecedented virtual field experiences, collaboration with different stakeholders helped them achieve the learning outcomes. A main drawback of the virtual field experience, however, impacted preservice Emirati teachers' motivation about online teaching.
Recommendations for Practitioners	Preservice teachers' technological skills should be reinforced and built to enable purposeful and practical technological integration in the teaching and learning process. Therefore, a holistic inclusion of all stakeholders' approach is needed to upskill and develop the competencies of all parties involved in the process taking into consideration a more enriching collaborative manner. Such a redesign should be examined to assess its validity and efficiency on a wider and more diverse sample to ensure its reliability and success.
Recommendations for Researchers	Researchers are recommended to explore the impact of virtual field experience on young children learning and engagement by including all stakeholders involved in the teaching and learning process, especially young students' parents since findings showed that children under the age of eight are at a disadvantage in online learning.
Impact on Society	Implications of the findings of this study show that sustainable virtual field experiences can be attained through a collaborative approach. Collaboration is essential as it enables preservice teachers to succeed in implementing inclusive pedagogical approaches.
Future Research	Further studies can enrich the findings of this paper by expanding the collected data to provide deeper and more generalizable results. For example, virtual student teachers' and school students' scores should be collected and compared to face-to-face scores in order to assess and evaluate the learning itself.
Keywords	preservice teachers, virtual field experience, technology integration, collaborative learning, teacher preparation program

INTRODUCTION

The global pandemic, COVID-19, has presented significant challenges in the education sector. The pandemic forced many learning institutions to close as a preventative measure to reduce the spread of the virus. Despite this closure, learning did not stop in the United Arab Emirates (UAE) as schools and universities implemented emergency remote teaching strategies very fast. The transition from face-to-face classes to online learning was not a big issue in ordinary theory modules. The challenge was with practical subjects, for example, field experience, which is completed by preservice teachers with learners in schools. Moyo (2020) postulates that one of the greatest challenges faced by teacher training institutions across the globe was related to the handling of practicum modules since preservice teachers were used to completing them in physical classrooms. Because schools switched to online learning, preservice teachers had no choice but to complete their field experiences virtually.

There was no other way for preservice teachers to do their practicum module without being involved in the teaching experience as it is the initial and most influential opportunity that will cultivate the development of their teaching practices (Cohen et al., 2013; La Paro et al., 2014; Rock et al., 2012). During field experience, teachers practice and evaluate the knowledge they have built through their formal years of education. However, the unprecedented pandemic forced schools to shift to online learning and, as a result, the field placement needed to shift to an online or virtual mode. Recent literature (i.e., Ersin et al., 2020; Varela & Desiderio, 2020) indicated the need for teacher preparation programs to prepare preservice teachers with new skills and strategies that would equip them for online teaching in virtual field placements. For instance, the virtual field placement demands for preservice teachers to have digital knowledge and literacy, online classroom management skills, online assessments, and evaluations of students' academic needs without being able to see them or interact with them (Varela & Desiderio, 2020).

There exists ample literature that focuses on preservice teachers' attitudes, perceptions, and experiences of virtual field experiences during the time of COVID-19 (Ersin et al., 2020; Hojeij & Baroudi, 2021; Mardiana, 2020). These include preservice teachers' experiences of virtual field experience (Hojeij & Baroudi, 2021), attitudes (Mardiana, 2020), and competencies (Ersin et al., 2020). However, there is a dearth of scholarship on the effects of field experience on preservice teachers (Soong et al., 2020) and faculty perceptions of virtual field placement experience in teacher education programs. A lack of knowledge in faculty perceptions is worth examining as they help improve the state of remote teaching and learning in general and virtual field experiences in particular as their thoughts (faculty) impact preservice teachers' performance (Şerife & Gökdaş, 2021). Considering the novelty of the phenomenon of virtual field placement, it becomes significant to explore faculty's perceptions as these perceptions influence their role and the support they provide to prepare their students (preservice teachers) and help them overcome challenges they might face (Hojeij et al., 2021). To this end, the study aims to answer these research questions:

1. What are the factors that influence faculty's perceptions of virtual field experience placement?
2. To what extent does the collaboration between key stakeholders impact the success of the virtual field placement?
3. How can teacher education programs improve virtual field placement?

LITERATURE REVIEW

VIRTUAL FIELD EXPERIENCE

Whether field experience is completed virtually or face-to-face, it remains the most indispensable element for preservice teachers' training. The field experience engenders professional transformation, reflection, and growth among preservice teachers (Moyo, 2020). Smith and Lev-Ari (2005) concur that field experience is a valuable component of teacher training as it prepares them to handle classroom realities (Grudnoff, 2011) and enables preservice teachers to link theory with practice in an authentic classroom setting (Ersin et al., 2020). Although COVID-19 compelled educational institutions to carry out field experience virtually in many different countries, it provided preservice teachers with the opportunity to practice teaching and it boosted their digital literacy (Ersin et al., 2020; Hojeij & Baroudi, 2021). This is why Şerife and Gökdaş (2021) recommended that all preservice teachers should be afforded an opportunity to do virtual field experience at least once in their study program. This prepares them to be able to teach effectively and to provide adequate support to all children in a physical classroom and online. Hixon and So (2009) contended that when preservice teachers participate in traditional face-to-face field experience, their opportunities are limited to what happens in a single classroom with one mentor school teacher. This is different from virtual field experience, which enables preservice teachers to be exposed potentially to different teaching environments and strategies. Therefore, it is important for preservice teachers to be exposed to teaching in a physical classroom as well as online as this is a needed contemporary skill set in education (Cahapay, 2020).

Such skills are needed not only during the time of COVID-19 but also beyond the global pandemic. The five essential benefits of using technology in field experience projected a decade ago, are detected in the current situation where practicum is conducted online. These benefits are: (a) exposure to various teaching/learning environments, (b) creation of shared experiences, (c) promoting reflectivity, (d) preparing students cognitively, and (e) learning about technology integration (Hixon & So, 2009, p. 296). When the global pandemic of COVID-19 is over, teaching and learning are less likely to return to the way it was before, as articulated by the International Commission on the Futures of Education (2020, p. 3) "We cannot return to the world as it was before." This has implications in the education sector as schools may implement online teaching modalities, which means offering virtual field experiences for preservice teachers. Cahapay (2020) postulates that the education sector is likely to adopt online learning strategies when the current pandemic is over. Sintema (2020) concurs that in the Zambian context, digitized virtual classrooms are likely to occur, which makes the need for a virtual field experience indispensable. This is so, because "many schools are headed towards complete online modality or blended learning modality in instruction" (Cahapay, 2020, p. 3) after COVID-19.

Field Experience in Different Contexts

Özüdoğru (2021) argues that one of the challenges faced by Turkish students during remote learning is that they could not do practice-based courses (such as practicum teaching) effectively as they used to do prior to COVID-19. Preservice teachers were reported to have faced pedagogical, technological, and social-emotional related challenges that made it hard for them to complete their field experiences (Özüdoğru, 2021). Students found it difficult to function in online classes independently, which affected lesson time allocation and efficiency (Evagorou & Nisiforou, 2020). This is different from what Ersin et al. (2020) reported, that in Turkey, online field placement was successful as preservice teachers were able to teach effectively and overcome technical problems.

Flores and Gago (2020) contended that, in Portugal, initial teacher education was faced with a challenge for preservice teachers to complete virtual field experience. Preservice teachers had different experiences with field placement. They did not find the switch from the physical classroom to the online experience easy. As a result, preservice teachers in Portugal who did virtual field experiences encountered some constraints that included the lack of internet access or lack of equipment, as well as a deficit in terms of digital literacy. In some cases, pupils did not possess the required equipment either because they did not have a laptop or a tablet; consequently, they had to share the same equipment with other family members. In other cases, there was no internet access or there were technical problems. In addition, some pupils found it difficult to navigate the online platforms to communicate and to find the tasks requiring a solution (Flores & Gago, 2020, p. 6).

Virtual field experiences are dependent on the availability of infrastructures such as the internet and electronic devices. In the Zimbabwean context, Moyo (2020) states that field experience could not occur at all as the country did not have any infrastructure that enables virtual field experience to take place. If the country does not have a system enabling school children to do online learning, there will be no way for preservice teachers to carry out the field experience. Şerife and Gökdaş (2021) reported that preservice teachers who participated in their study claimed that if they had a choice, they would opt for face-to-face field experience over the virtual one. The majority of the preservice teachers who preferred a face-to-face experience chose it because of the physical interaction that happens between the teacher and learners and amongst the learners themselves. This is similar to a study conducted in Australia where teachers had concerns about students' engagement online (Cruickshank et al., 2021). Engaging students online presents difficulties, but they are surmountable; if the person is adequately skilled, it can be achieved. Draves (2013) argues that students' engagement in online learning is pivotal and that it leads to meaningful learning and the achievement of educational goals. Students' interaction in online learning requires a social cognitive presence, and a teacher's presence to be established, resulting in the creation of an online learning community (Garrison et al., 2001).

Faculty's Perceptions of Field Placements

While worldwide literature focuses on measuring the perceptions, attitudes, and skills of preservice teachers in their field placements (i.e. Evagorou & Nisiforou, 2020; Luo et al., 2017), exploring faculty's perceptions is as equally important as these influence the quality of coaching and supervision offered. In the field placement, the faculty's role is more of a mentor who scaffolds the learning experience of preservice teachers. As such, the theoretical framework of this study is based on Vygotsky's (1978) concept of scaffolding that entails a more knowledgeable or skilled individual (the faculty) supporting a lower-skilled individual (the preservice teacher) to achieve the targeted goals (practice teaching). The concept of scaffolding and the zone of proximal development generate from Vygotsky's (1978) sociocultural theory. The zone of proximal development is described as the distance between what learners can do themselves and what they can achieve with the help of others. Therefore, scaffolding stimulates learners to learn, perform, and solve complex tasks that they cannot do on their own (Chen & Law, 2016).

In the context of this study, scaffolding happens when faculty interacts, discusses, and collaborates with preservice teachers to increase their performance and help them solve complex problems and challenges. The faculty acts as a mentor guide and supports preservice teachers with the implantation of teaching methodologies in real classrooms. Faculty ensures that preservice teachers are designing engaging lesson plans and assessments that are aligned with the learning outcomes. They model effective teaching techniques and monitor preservice teachers' performance and competencies (Clark et al., 2015). That being said, the perceptions and attitudes of faculty towards the field placement experience are highly connected with the quality of scaffolding and supervision offered and impact the overall field placement experience. This finding is evident in a recent study conducted in the UAE where eleven faculty supervisors revealed the factors in field placement that can directly impact their attitudes (Hojeij et al., 2021). Having a well-structured field placement program where the roles of preservice teachers, school mentors, and faculty supervisors are identified and agreed upon from one side and increasing the communication channels and collaboration between faculty, the school mentors and preservice teachers from the other side are among the factors that impact faculty's attitudes and enhance their experience (Boholano, 2017; Hojeij et al., 2021). Luo et al. (2017) highlighted the importance of building strong relationships and channels of collaboration between main key stakeholders for a positive online teaching experience for preservice teachers. This result had a greater impact on preservice teachers' perceptions of online teaching as they began to feel that online education could be equivalent to traditional education (Luo et al., 2017, p. 1). On the other hand, teaching young children online posed many challenges for preservice teachers and faculty as children learn best using hands-on activities and play, which are hard to attain in online learning (Kim, 2020). About 80% of the teachers reported that it was not easy to teach and engage with young children online (Fauzi & Khusuma, 2020). A survey conducted with more than 3,275 parents in the Chinese context found that the majority preferred face-to-face instruction when teaching young children (Dong et al., 2020).

Earlier studies like Boholano (2017) and Zeichner (2010) stressed the need for field placement programs to be well coordinated and structured so faculty can succeed in preparing preservice teachers to overcome the various challenges of teaching practices. It is also suggested that universities establish a system of rewards and recognitions for faculty to encourage them for conducting action research to solve contextual problems and advance the quality of field placement programs (Zeichner, 2010). Enhancing faculty's attitudes about the impact of the field placement on preservice teaching practices is also a catalyst to improve the quality of this experience. However, little is known about faculty's attitudes and perceptions (Cuenca, 2010), in particular with the sudden shift of these programs from face-to-face to online. Therefore, more research is needed to provide evidence about the impact of field placement programs and learn from the lessons that faculty faced during the virtual field placement that took place during the pandemic. A qualitative approach is adopted to capture faculty's perceptions in order to understand their experiences during this phenomenon and obtain a precise and overall picture of reality (Merriam & Tisdell, 2015).

METHODOLOGY

RESEARCH DESIGN

Online field experience was implemented for the first time in the Early Childhood Education Program in the context of the study due to the unprecedented pandemic. Considering the novelty of this phenomenon, an exploratory qualitative research design was followed to arrive at an in-depth description (Merriam & Tisdell, 2015) of the faculty's perceptions. This approach helped the researchers follow an inductive investigative strategy through qualitative means to search for meaning and understanding of the phenomenon from the participants' views. The advantage of the phenomenological approach is that it focuses on the lived experiences of the subjects and their interpretations in order to depict the essence of the phenomenon. Hence, the role of the researchers in the phenomenological approach was to analyze and compare these interpretations in order to draw comparisons and gain insights about the phenomenon and comprehend its essence.

PARTICIPANTS

Merriam and Tisdell (2015) suggested that studying a small number of subjects would help the researchers gain an in-depth understanding of the phenomenon and enrich the findings of the study. This convenience sampling assisted the researchers in capturing the essence of the subjects' experiences and in discerning shared patterns and developing themes (Creswell, 2009). The sample in this study consisted of five faculty members in the College of Education at one university in the UAE. All participants had more than five years experience teaching and supervising students in higher education, they all had PhDs, and all were responsible for conducting virtual field experiences.

The faculty members experienced the supervision of preservice teachers in an online field placement for the first time in the period of one full semester during their teacher preparation program. Preservice teachers are undergraduate Emirati students in an Early Childhood Education Teacher (ECE) preparation program. This program entails that preservice teachers undertake four field experience placements throughout their 8-semester course of study at a partner school. This study is conducted during the eighth semester, where preservice teachers were required to spend ten nonconsecutive online teaching days at an elementary school where they were each paired with a school teacher mentor, who is the classroom teacher. The role of the mentor teacher was to assign the lessons to preservice teachers, observe them in action, and give constructive feedback about their teaching. During the virtual field placement, preservice teachers joined the online classes using Microsoft Teams. Most of them were prepared to use this platform one week before they started teaching. Each faculty was assigned eight preservice teachers. The role of the faculty was to guide them during their online field experience and ensure that they met the course requirements. Additionally, the faculty members were expected to liaise with the mentor teachers and scaffold the work of the preservice teachers to enhance their virtual field experience. All of this was done online due to the COVID-19 quarantine.

DATA COLLECTION

Interviewing is the best technique to use when conducting a phenomenological study of a few selected individuals because it helps participants share their experiences and reflect on themselves (Merriam & Tisdell, 2015). One-on-one semi-structured interviews were conducted on Zoom with the participants and each interview lasted for about 30 to 45 minutes. The use and confidentiality of data and anonymity of the participants' personal information were guaranteed before the start of the interview. The identity of participants was protected by allocating numbers (from 1 to 5) as pseudonyms. Verbal consent to video-record the interview on Zoom was obtained. It was important that participants have their cameras open during the interview in order for the researchers not to miss any visual cues from the participants and allow the researcher to take notes of their facial expressions to capture indications of their emotions. Additionally, the participants were assured that their participation was voluntary, and they could withdraw from the interview at any time.

The interview questions were developed to serve the purpose of the study and generate themes to construct an overall understanding of the faculty's experience during the online field placement of preservice teachers. As such, the first question aimed at understanding the highlights and the challenges of the virtual field placement as experienced by the faculty members. The second question was to collect participants' views about the benefits and challenges that preservice teachers faced during online field placement. The third question aimed at understanding how preservice teachers used technology in online instruction to stimulate students' learning and engagement. The fourth question was about the online classroom management skills of preservice teachers. The fifth question was designated to seek further recommendations from the faculty's point of view to improve the virtual field experience. Follow-up or probe questions (i.e.: What do you mean? Tell me more about that. Give me more about that. And so on.) were also asked to seek more information or clarity about the participants' answers.

Data Analysis

An inductive data analysis was followed to identify units of data from interview transcriptions. The researchers manually analyzed the data and worked reiteratively between these units of data by assigning codes to each input using an inductive approach (Braun & Clarke, 2006). Then these codes were color-coded. Assigned codes were based on the participant's response to the specific question asked (Braun & Clarke, 2006). After that, the researchers compared the units of data and organized them into tentative categories or themes in order to capture some recurring patterns that cut across the data and then systematically compared and grouped these categories (Creswell, 2009). As this data analysis process continued, the researchers moved from an inductive to a deductive stance to determine a final set of four categories that remained solid throughout the analysis (Merriam & Tisdell, 2015). Table 1 shows these categories and sub-categories.

Table 1. Categories and sub-categories

CATEGORIES	SUB-CATEGORIES
Enhanced collaborative learning	Collaborating with school mentor teachers. Developing relationships with school mentor teachers. Collaboration between faculty members, school principals, and coordinators. Sharing information. Using various available digital communication tools
Building relationship with school mentor teachers	Lessened faculty's stress level. Provided faculty with feedback about preservice teachers. Increased preservice teachers' commitment and motivation levels.
Drawbacks of virtual field experience	Lack of classroom teacher-student and student-student interaction in online learning. Difficulties for preservice teachers to manage students' learning and behavior in an online classroom. Preservice teachers' inability to differentiate the instruction as per students' needs. Classroom students' disengagement and motivation. Not taking virtual field experience seriously by preservice teachers. Reduced preservice teachers' responsibility.
Recommendations for improvement	Training or professional development sessions on the use of technology for faculty. Recruiting dedicated school mentor teachers. Providing technological professional development for preservice teachers before the field experience. Strengthening relationships among faculty.

RESULTS

This section presents the results of the study categorized according to emerging major themes: enhanced collaborative learning, building relationships with school mentor teachers, drawbacks of virtual field experience, and recommendations for improvement.

The majority of the faculty member participants in this study perceived that the preservice teachers had a positive virtual field experience. Preservice teachers felt that the field experience opened new horizons and gave them opportunities to put the skills they learned in their teacher preparation course into practice. This new experience exposed preservice teachers to technology and trained them on selecting and integrating technology into their online instruction. The following excerpts from Participants #2 and #5 respectively support this view:

> Preservice teachers were exposed to a very new experience, but it opened new horizons for them because in the educational field, we are always going to have online learning as an element within probably a hybrid or blended learning model.
>
> Having the experience to immerse in such a model during their internship experience, I would say it was a valuable learning experience.

Preservice teachers had an opportunity to use the knowledge and the skills they developed in their course work just like in a real-life situation. They had the opportunity to practice what they learned at the university in a technology course; for them, it was putting theory into practice. Learning was taking place during a virtual field experience. There was much reflection as preservice teachers would have the opportunity to watch their recorded lessons and reflect. This was confirmed by Participant #1:

> Another advantage [of virtual field experience] is that their observations were recorded, and I was able to observe them, but the preservice teachers were also able to observe the recordings and reflect on their teaching which would not have happened previously under normal circumstances.

ENHANCED COLLABORATIVE LEARNING

One of the recurring positive aspects of the virtual field experience successes among participants was collaboration. In face-to-face classes, school mentor teachers had challenges meeting with faculty members to discuss preservice teachers' performance, but through virtual field experience, the level of collaboration between faculty members and school mentor teachers was enhanced due to the development of relationships and information sharing through the use of technology (i.e., WhatsApp). Participant #3 reported, "I had an open communication with the school mentor teacher and I felt that my relationship with her developed.". Collaboration during virtual field experience was not only limited to faculty and school mentor teachers. There was also an efficient and effective collaboration between faculty members, school principals, and coordinators where they used WhatsApp to create a group and communicate about any challenges faced and helped each other solve them. Participant #3 explained:

> I managed to establish very good communication with over five principals and coordinators. We exchanged information without any delay in the first two weeks. What helped us do that is the WhatsApp group that we created and it made our job easier as we provided immediate help to preservice teachers.

This collaboration and information sharing was facilitated by the availability of various digital communication tools as explained by Participant #1:

> There was an opportunity to collaborate with the school mentor teachers in more flexible ways. Sometimes the school mentor teachers would say, "You know I don't have time, or I have got a meeting, or I have to be here or have to be there," so catching up with them and having time to spend with them when it was face-to-face was a big challenge. But virtually, it is like, "Oh let's get on [Microsoft] teams, or you know I am free at this time, let us connect also through WhatsApp." We are using a lot of technology and are becoming more innovative. I think that is something that has come as a result from having the experience online.

BUILDING RELATIONSHIPS WITH SCHOOL MENTOR TEACHERS

The impact of the mentor-preservice-teacher relationship on the virtual field experience was noticeable in the participants' responses. Having a positive working relationship between school mentor teachers and preservice teachers and developing a collegial relationship between them reduced preservice teachers' stress levels making this new experience smooth. Participant #4 mentioned:

> 100% of preservice teachers had a really nice, decent relationship with their school mentor teachers. From the start they collaborated, they knew the rules, and they started building the relationship in a nice, positive, and progressive way. They just adapted very well with the school mentor teachers, they understood what they were supposed to do, and they started applying it.

Participant #5 reported that he gained a lot of insight into preservice teachers through a collaborative approach he was using. The approach involved collaboration with his students (the preservice teachers) on a one-on-one basis and working closely with school mentor teachers. This participant reported on the nature of the collaboration he had online, saying:

> I set up on days that they [preservice teachers] were not working with their school mentor teachers. I scheduled one-on-one sessions with my entire class, and I had a series of questions that I asked them about how their experiences were going, what they were doing, and so on. So, that gave me a lot of insight into what was happening with each one of the preservice teachers, and I also reached out to school mentor teachers and asked them to give me updates in writing on what was happening with them. So, I was able to use the school mentor teacher's feedback in my one-on-one sessions.

Furthermore, it was notable that the collaborative relationship established among faculty members, school mentor teachers, and preservice teachers helped them become more committed and motivated. According to Participant #2:

> I had mentors who were fully committed and motivated to providing the preservice teacher with the best mentor-mentee experience they could have, and for me that just made my job easier. So, I thought that was positive, and it also provided the preservice teachers with a good mentor relationship and experience, I believe, because there was a balance between encouraging them and also pushing them and holding them accountable. I really had a lot of confidence in the school mentor teachers.

Challenges Encountered During Virtual Field Experience

Despite the fact that faculty members perceived that the virtual field experience was successful as the stated learning goals were achieved, they acknowledged the presence of some challenges. The first challenge emerged from the lack of interaction which resulted in preservice teachers preferring face-to-face teaching over online. Lack of interaction in online learning was noted as the greatest challenge which made preservice teachers' virtual field experiences difficult. Participant #2 said, "The preservice teachers missed a lot as they were not able to actually interact with each and every learner in a class. We cannot underestimate the value of face-to-face interaction with young children."

This challenge imposed more limitations, particularly on classroom management, young children's engagement, and differentiation of instruction. Faculty reported that it was very difficult for preservice teachers to involve young children in their online classes and increase their engagement. That is why they preferred face-to-face instruction after the global pandemic. Another participant reported that it would be better to implement blended learning so that preservice teachers get a chance to engage learners in face-to-face classes and also teach online. Participant #4 said:

> If there were other possibilities, for example an opportunity for preservice teachers to have some blended face-to-face teaching with young children maybe once per week and then alternate the following week. It would be great for them as they would be able to have the best of both worlds. They would be able to have that face-to-face interaction, they would get to see those learners, and they would get to call them to order. They would get to do things like small group instruction, which they have not been able to do well. With the current structure, it is not possible.

Furthermore, faculty members reported that not all preservice teachers were motivated and ready to do their field experience virtually. This was the first virtual field experience when the pandemic started and as a result, preservice teachers had a lot to deal with, including stress caused by the pandemic and the need to adapt to doing field experience virtually. All faculty members reported some challenges which were mainly related to the lack of preservice teachers' motivation which negatively impacted their abilities to take responsibility for their learning. Participant #1 said:

> The main challenges had to do with the preservice teachers that were unmotivated. They did not take this seriously. I had one situation with a preservice teacher who complained about the school mentor teacher. But, when I met the mentor and had an actual phone conversation with her, the mentor said, 'No, I'm just holding the preservice teacher accountable because she is missing out and coming in late. She is not doing what I'm asking her to do and didn't do the mini lesson. So, the preservice teacher started to talk about wanting to switch mentors and that was a challenge."

Similarly, Participant #5 echoed the same sentiment about some preservice teachers not taking the virtual field experience seriously by saying, "I found it difficult to get the girls to come to zoom meetings. I would hold meetings and only three of them would come … I just felt that the level of professionalism experienced wasn't great." Preservice teachers' failure to hold themselves accountable for their learning resonated with the idea of getting them to develop a growth mindset and this was reported as a challenge by Participant #2:

> I think the biggest challenge was getting preservice teachers to have a growth mindset. You know about the whole shift. At first, it was a bit of a challenge. Preservice teachers were asking about how this was going to work. How am I supposed to teach if I can't see the students? And so I think just trying to get them to a place of comfort and ease by telling them that we don't need to get stuck, let's progress, and let's think of ways that we are going to get through and we can manage as opposed to what we can't do. Let's talk about what we can do.

Recommendations for Improving Virtual Field Experience

Participants recommended that in order to improve the virtual field experience, there is a need for some training or professional development sessions held with all stakeholders. Participant #4 said:

> School mentor teachers and preservice teachers should be trained at the beginning of field placement on the use of the technology. I think they should have one week in advance of communicating with school mentor teachers before going to classes and start delivering instructions. This would really be helpful for all parties.

Another participant reflected on the importance of recruiting dedicated school mentor teachers and training them along with their school administrators. Participant #2 said:

> Sourcing schools that are of a good quality of teachers and administration is important. I do not think that every mentor needs to be experienced, I think that every mentor needs to be willing to learn, needs to be consistent and understands what's expected. I think that he/ she should go to mentor training. I think that administrators need to be part of the training as well. Whatever orientation we give to the administration, it needs to be part of the training so that administrators are spoken to directly. Here is what we need from you, and here is what we need from the mentors.

Participant #1 reiterated the need to emphasize training or coaching preservice teachers before they go out to do virtual field experiences. He stated:

> We need to provide online professional development for preservice teachers before going to the field, just to check with them, to make sure they have got the necessary skills and they know how to do it…You are surprised that they need some help with very small stuff. For example, small tips to do things right, going to build up an online activity, making proper power point presentation with correct font size, color, background, and how to make the presentation attractive.

If different professional development sessions are conducted with faculty members, school mentor teachers, and preservice teachers prior to the commencement of field experiences, that will help reduce some obstacles. Participant #5 reported that different faculty members were not giving preservice teachers the same information:

> The instructors need to work more closely together. I feel different instructors are giving the preservice teachers different information, and I feel it will be nicer if we chunk it up and have all the preservice teachers together in one class with all the instructors. The instructors would plan what they want to do with their preservice teachers, so we are all on the same page because it was just a weird experience. So, I think working together would eliminate confusion and I think that the instructions were too many, the handbook, and this form and then do that on task stream and do that on Blackboard.

DISCUSSION

Collaboration that was perceived during the virtual field experience in this study is essential as it is one of the four critical skills of the 21st century. The other three are communication, critical thinking, and creativity. Boholano (2017) argues that collaboration is one of the three essential critical skills that is needed by all students in order to stay competitive in a fast-changing job market. The start of COVID-19, which has brought unprecedented changes in education, has made the job market change faster where preservice teachers had to complete field experience virtually. Despite the fact that collaboration is hard to attain in online learning, it remains the key component in the virtual field experience (Luo et al., 2017). Vygotsky (1978) postulated that in any learning environment (either face-to-face or online), collaboration is indispensable. In this study, the level of collaboration, guidance, and support strengthened the relationships between preservice teachers, school mentor teachers, and faculty helped preservice teachers to progress and reach their zone of proximal development. Hence, the findings of this study concur with earlier findings of Luo et al. (2017) that creating positive relationships online among key stakeholders improved faculty and preservice teachers' perceptions about the virtual field placement and created an online community (Fiock, 2020). This is so because, through collaboration, school mentor teachers are trained by faculty to minimize inconsistencies and inefficiencies. Through collaboration, relationships between school mentor teachers and preservice teachers were enhanced as the former guided the latter. This concurs with Vygotsky's (1978) concept of scaffolding, where a more knowledgeable and skilled person provides support based on the student's needs. The support is gradually removed as the student's ability to perform a particular task increases.

Preservice teachers' inability to engage young children in online learning was reported by faculty members as one of the main challenges they had during the virtual field experience. This finding resonates with the World Bank's (2020, p. 12) statement about the unsuitability of online learning among young children: "Early childhood education and foundational learning in early primary school, in particular, are likely to be negatively impacted … because children at this age (0–8 years) are less able to independently take advantage of remote learning programs and tools". Similarly, this finding concurs with previous research (i.e., Fauzi & Khusuma, 2020; Kim, 2020) affirming the difficulties to engage young children in an online classroom which impacts faculty and preservice teachers' perceptions of virtual field experience negatively. While this claim is well supported by empirical evidence, the virtual field experience can be seen as an opportunity for teachers and students alike to acquire skills needed in a digital-based environment. The 21st century requires preservice teachers to acquire knowledge and skills that allow them to be able to teach face-to-face and online (Boholano, 2017). The way teacher candidates are being prepared has changed, and there is a focus on online teaching since it has become the eminent skill needed in response to the global pandemic of COVID-19 (Evagorou & Nisiforou, 2020). After the pandemic, all preservice teachers are going to need both face-to-face and online skills for future careers (Luo et al., 2017). Hence, the findings of this study support previous claims made by Hojeij and Baroudi (2021) for preparing preservice teachers with the use of technology before going to classes and start delivering instructions. Curriculum designers are recommended to redesign teacher preparation programs to expand teachers' knowledge about the available technologies and how to use them with their online instruction.

Furthermore, it is noteworthy to mention the additional factors that hindered the field experience and negatively impacted the faculty's perceptions. Lack of student engagement and motivation caused chaos and increased students' misbehavior in the online classroom which limited preservice teachers' ability to manage the classroom, know the student's academic needs, and differentiate the instruction according to their needs. In this case, the role of faculty as a mentor and guide was also threatened as they could not provide adequate support to preservice teachers considering their limited familiarity with individual students' needs. Unlike the findings of Luo et al. (2017), this result affirms that preservice teachers in the UAE preferred face-to-face instruction. Furthermore, students' and preservice teachers' limited technical knowledge and skills impacted their performance in the online classroom. This finding supports previous results of Flores and Gago (2020), Garrison et al. (2001), and Özüdoğru (2021) suggesting the necessity to train students and preservice teachers with the use of technology to increase the social cognitive presence and create an online learning community. As a result of these hindrances, faculty participating in this study expressed their worries about the lack of motivation and responsibility of Emirati preservice teachers that seemed to have been caused or exacerbated by the online setting. Therefore, it is argued here that the goals of the virtual field experience were not truly met, and similar to their worldwide peers, Emirati preservice teachers found it hard for them to complete their virtual field experiences.

Recommendations and Limitations

This paper focused on the perceptions of faculty members on Emirati preservice teachers' virtual field experiences during COVID-19 while using a phenomenological approach. This study examined these experiences on a small scale by analyzing in-depth the interpretations of experiences to catch the essence of the lessons learned. Thus, the framework put forth in this study could serve as a guideline for teacher education programs, especially field experience preparation. Hence, students' technological skills should be reinforced and built to enable purposeful and practical technological integration in the teaching and learning process.

The implication of the findings of this study shows that sustainable virtual field experiences can be attained through a collaborative approach. Collaboration is essential as it enables preservice teachers to succeed in implementing inclusive pedagogical approaches. Therefore, a holistic approach that is inclusive of all stakeholders is needed to upskill and develop the competencies of all parties involved in the process taking into consideration a more enriching collaborative manner. Such a redesign should be examined to assess its validity and efficiency on a wider and more diverse sample to ensure its reliability and success.

Nevertheless, the paper has a few limitations in its findings. First, the number and homogeneity of the chosen sample present limitations as it precludes generalizing the results attained. Second, the short timeline of the study across one semester of preservice teachers' field experiences that occurred at the beginning of the COVID-19 pandemic poses another limitation, as the whole world was struck unaware with global stress and a general disruption of previous practices. Thus, it could not proceed and inspect (1) the impact of the virtual experience on students' academic achievements and their future careers, (2) the online assessment of students' learning, and (3) early childhood school students' perceptions. In fact, further studies can enrich the findings of this paper by expanding the collected data to provide deeper and more generalizable results. For example, virtual preservice teachers' and school students' scores should be collected and compared to face-to-face scores in order to assess and evaluate the learning itself.

Hence, further studies are recommended to widen and vary the sample chosen to be studied and to include all stakeholders involved in the teaching and learning process especially young students' parents since findings showed that children under the age of eight are at a disadvantage in online learning.

CONCLUSION

The purpose of this study was to examine faculty perceptions of virtual field placement of preservice teachers at a university in the UAE. The study concluded that although faculty perceived the implementation of online learning in early childhood as a mammoth task that impacted their motivation towards online teaching, collaboration allowed for the attainment of desired results. Being placed in an online field experience enabled preservice teachers to gain intelligible digital literacy and was an eye-opener for curriculum designers of teacher preparation programs. The study has far-reaching implications for society at large. There is evidence that sustainable virtual field experiences are attainable through a collaborative approach. This is consistent with Vygotsky's (1978) theory of social constructivism which places the interaction of stakeholders and scaffolding at the forefront. If we were to build adaptability in higher education, exploring faculty perceptions becomes the foundation for a successful teaching and learning experience.

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TPACK, ORGANIZATIONAL SUPPORT, AND TECHNOSTRESS IN EXPLAINING TEACHER PERFORMANCE DURING FULLY ONLINE LEARNING

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ABSTRACT

Aim/Purpose	This study aims to analyze (1) the effect of organizational support on Technological Pedagogical Content Knowledge (TPACK), (2) the effect of organizational support and TPACK on teacher performance, (3) the effect of organizational support and TPACK on technostress, and (4) the effect of technostress on teacher performance.
Background	The disruption of Information Technology (IT) innovation in educational practice happened two decades ago. However, the more massive and intense IT integration in teaching and learning practice was demanded during the COVID-19 pandemic. These circumstances made teachers and students face a new teaching and learning environment with complete IT mediation. Therefore, they will

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	show a unique response valuable for managing effective education and further research regarding teaching and learning in the online environment.
Methodology	Using a purposive sampling technique, data was collected from 419 pre-service teachers in the economics and business field. The data was then tabulated and analyzed using PLS-SEM.
Contribution	This study connects the concept of TPACK as knowledge to organizational support and technostress as the organizational and personal response to deal with massive IT integration in fully online learning during the COVID-19 pandemic. This study bridges the educational concept of teacher competence to the behavioral framework of IS users to deal with the online environment. Teaching and learning are tasks that engage human-to-human interaction, which is different from other productive activities like the business sector. Therefore, this study may give fruitful findings, both theoretically and practically, to improve educational practice in this digital age.
Findings	Researchers found that organizational support and TPACK were valuable antecedents of teacher performance in an online environment. At the same time, technostress is not a critical threat to teacher performance. However, technostress exists among teachers and is uncontrollable by TPACK and organizational support. Researchers argue it is an unavoidable circumstance. The educational system demands a rapid shift to fully online learning due to the COVID-19 pandemic. Therefore, the teacher should accept the challenge to maintain the continuity of teaching and learning activities.
Recommendations for Practitioners	(1) Teachers' knowledge and organizational support should become an essential concern for policy makers and school leaders to maintain teacher performance in this dynamic online environment. (2) The educational leader should develop a strategy to manage technostress among teachers from another aspect beyond TPACK and organizational support. (3) Policymakers should develop a strategy to compensate for teacher effort and sacrifices resulting from IT disruption in their working experience.
Recommendations for Researchers	Researchers should confirm and refine the framework developed in the private sector to the educational sector to generate more theoretical and empirical understanding regarding the functional integration of IT devices on certain entities' productive tasks.
Impact on Society	This study gives more understanding of how teachers respond to IT-integrated tasks in their academic activity. This discussion will give more wisdom to understand the threshold of IT usefulness in the educational field besides giving preference to managing it to maintain teachers' work quality.
Future Research	Further research is required to identify the critical factors to manage teachers' technostress effectively. A qualitative research method may be helpful in exploring teachers' complex responses regarding IT-integrated tasks.

Keywords	online learning, COVID-19, physical distancing, teacher education

INTRODUCTION

Information Technology (IT) has accelerated innovation in learning practices significantly. Various studies have revealed the acceleration of learning quality through technology integration (Moreira-Fontán et al., 2019). In addition, researchers found that learning is more dynamic and richer with the help of IT combined with pedagogic practices (Badia et al., 2013; Ersanli, 2016; Koh et al., 2017). The knowledge that teachers need for this practice is called TPACK (Technological, Pedagogical, Content Knowledge) (Graham, 2011; P. Mishra & Koehler, 2006; Niess, 2011). Unfortunately, education in developing countries, including Indonesia, shows a different response. Researchers and education practitioners find that the challenges of this digital era are not enough to spur conceptual and practical knowledge related to IT-integrated pedagogy (Accilar, 2011; Effiyanti & Sagala, 2018; Georgsen & Zander, 2013; Kalolo, 2019; Miah & Omar, 2012). This condition has become more realized by various obstacles in fully online learning during the COVID-19 pandemic (Adarkwah, 2021; Alawamleh et al., 2020; Bao, 2020; L. Mishra et al., 2020; Zhou et al., 2020). Researchers suggest that teachers have various obstacles in online learning, both technical and pedagogical constraints, such as difficulty in using learning management systems, developing e-learning materials, adjusting the instructional design to the online environment, and maintaining student engagement (Adarkwah, 2021; Ali, 2020; Bao, 2020; Dumford & Miller, 2018; L. Mishra et al., 2020; Sun et al., 2017). Other researchers suggest that both teachers and students experience pressure or stress due to online learning (Effiyanti & Sagala, 2018; Li & Wang, 2021; Sim et al., 2021). This happened due to several factors including (1) limited literacy and technological efficacy of educators (Christensen & Knezek, 2017a; Effiyanti & Sagala, 2018), (2) limited specific and continuous IT-integrated pedagogic research (Cochrane, 2010), (3) limited knowledge transfer culture in educational organizations (Lu & Ramamurthy, 2011; Zeng et al., 2019), and (4) unequal access to IT infrastructure among educators (Sun et al., 2017).

The technostress phenomenon has existed and has been studied for a long time. Initially, the technostress phenomenon occurred because of the limitations of teachers in using information technology (IT) (Brod, 1984; Effiyanti & Sagala, 2018). However, nowadays, the phenomenon probably transforms into more complex circumstances such as high workloads, disruption of work-life balance, and job insecurity and uncertainty resulting from technological innovation (Ayyagari et al., 2011; Li & Wang, 2021; Tarafdar et al., 2010). The pressure in work is unavoidable because, in turn, IT will disrupt the work patterns naturally that have occurred so far for teachers. IT integration in learning requires teachers to make various changes in learning activities, including instructional design, learning media, teaching materials, and evaluation designs (Cochrane, 2010; Daniel, 2020; Sun et al., 2017). That issue has become more demanding when government regulations required full online learning due to the COVID-19 pandemic to prevent virus transmission (Daniel, 2020; Naciri et al., 2020; Zhou et al., 2020). In this situation, almost all teachers and educational institutions experience culture shock, and irritation occurs during the migration from face-to-face and blended learning to fully online learning (Sagala et al., 2021). The main problem is not solely on the teacher's computer skills but on the intensity of the increasingly massive use of IT and the specific tasks of using IT, such as learning activities (Cochrane, 2010; Sagala et al., 2021; Sun et al., 2017).

From an infrastructure point of view, accessibility to IT has no significant issue. Almost all academic staff in various regions have their own IT tools and are supported by the availability of open-source LMS that can be utilized by teachers and students anywhere (Sagala et al., 2021). Likewise, as explained earlier, irritation still occurs because of the unstoppable IT innovation and the increasingly massive intensity of its use in learning. Therefore, educational institutions, including schools and universities, must have an organizational support system that can reduce irritation during the migration process to online learning (Li & Wang, 2021). Furthermore, a support system should be used as an instrument to control teacher technostress in the implementation of online learning and mastering the teacher's computer skills in academic activities (Cochrane, 2010; Sun et al., 2017). For empirical justification, this study aims to analyze (1) the effect of organizational support on TPACK, (2) the effect of organizational support and TPACK on teacher performance, (3) the effect of organizational support and TPACK on technostress, and (4) the effect of technostress on teacher performance.

Previous studies have developed and investigated the importance of TPACK in educational practice in this digital era (Graham, 2011; P. Mishra & Koehler, 2006; Niess, 2011). At the same time, several research projects have analyzed the negative impact of technostress on end-user computing and the importance of organizational support to control the risk among organizations' human resources (Ayyagari et al., 2011; Effiyanti & Sagala, 2018; Li & Wang, 2021; Ragu-Nathan et al., 2008; Sim et al., 2021; Tarafdar et al., 2011). Besides, knowledge was seen as the crucial factor that makes ICT become a valuable tool (Cochrane, 2010; Grant, 1996; Sredojević et al., 2016; Sun et al., 2017). Factually, schools still face irritation during full online learning implementation, especially in developing countries. Scholars reported that schools are still not yet controlling the ICT migration carefully (Adarkwah, 2021; Christensen & Knezek, 2017b; Effiyanti & Sagala; Kalolo, 2019). Additionally, previous research regarding technostress, organizational support, and knowledge management regarding ICT integration and migration is still dominated by private sector organizations. Therefore, this study wants to bridge those gaps by using TPACK as the knowledge aspect that is specifically used to proxies teacher-specific responsibilities. This study also wants to enrich the findings regarding the technostress phenomenon and its controllable construct to maintain individual performance in the educational sector. The current study is important as a theoretical and empirical foundation to deliver teaching and learning qualities in the digital environment.

A second-order construct measures the TPACK, Organizational Support, and Technostress variables in this study because of the broad dimensions of these variables. A second-order analysis is also done to obtain a holistic capture of the phenomenon to gain implications for making the right decision. In addition, this study can contribute to the management of technostress for teachers so that educational institutions can consistently provide meaningful learning amidst the uncertainty of learning practices due to technological disruption.

LITERATURE REVIEW

UTILIZATION OF IT INVESTMENT

The euphoria of the presence of technology promises innovation in professional practice in various fields, including education. From the utility point of view, the usefulness of IT is measured by reviewing the increase in productivity and time utilization of an IT innovation and investment (OECD, 2000). IT researchers believed that productivity and time utilization would impact economic growth (OECD, 2000; Pohjola, 1998, 2000). However, IT investment must be followed by education investment (OECD, 2000; Rebelo, 1998). This view shifts Solow's neoclassical perspective, which believes that IT investment is the critical factor determining productivity (Rebelo, 1998; Sredojević et al., 2016). Endogenous researchers offer theory X, which suggests endogenous variations in determining the usefulness of IT investments that lead to knowledge acquisition (Grant, 1996; Rebelo, 1998; Sredojević et al., 2016). Knowledge acquisition is seen as a driver of optimizing the benefits of IT investments (Grant, 1996; Sredojević et al., 2016). Therefore, IT investment must continuously innovate certain professional practices to create optimal value-added according to a particular field of work (Rebelo, 1998). At this critical point, every organization, including educational organizations, must possess the creation and mastery of new knowledge. Educational investment can be directed at mastering competencies related to the use of IT in optimizing academic activities. In turn, the availability of IT will help innovate pedagogical practices following teachers' and schools' specific needs.

TPACK AND ORGANIZATIONAL SUPPORT

In 2006, P. Mishra and Koehler formulated a new knowledge framework called Technological Pedagogical Content Knowledge (TPACK). TPACK is built on the framework of Shulman (1986, 1987), who developed the concept of Pedagogical Content Knowledge (PCK) that suggests that pedagogic knowledge has to be adapted to specific needs in teaching certain learning content (Koehler et al., 2013). P. Mishra and Koehler (2006) added technological knowledge to accommodate IT integration needs in learning in the digital era based on this framework. P. Mishra and Koehler view that teachers need to master technological, pedagogical, and content knowledge that is equivalent and blend in with each other to integrate technology in optimizing learning. From this mix of expertise, there will be slices of knowledge that interact with each other so that teachers can design their teaching and learning activities to fit the content material and utilize the right technology (Koehler et al., 2013; Schmidt et al., 2009).

This knowledge need is theoretically relevant to the endogenous theory, which suggests that technology investment success is determined by various endogenous factors, including organizational readiness, policy support, and mastery of knowledge (OECD, 2000; Sredojević et al., 2016). Likewise, although this knowledge framework was initiated more than a decade ago, various studies still show teachers' difficulties in integrating IT into learning (Effiyanti & Sagala, 2018). This difficulty has become increasingly apparent when fully online learning was implemented during the COVID-19 pandemic, especially in developing countries (Adarkwah, 2021; Naciri et al., 2020). This phenomenon indicates teachers' and schools' slow absorption of knowledge in certain areas.

The publication of the TPACK concept was followed by various professional training classes to maintain the continuity of the development and practice of TPACK in the classroom (Jang, 2010; Koh et al., 2015; Niess, 2011). However, the accessibility of teachers to training is not evenly distributed in certain areas. In addition, the conditions faced by teachers in schools are undoubtedly different. Ragu-Nathan et al. (2008) observed this phenomenon with situational factors. Situational factors are organizational mechanisms that produce variations in responses from organizations and their members regarding the use of IT in their productive activities (Ragu-Nathan et al., 2008). Many factors may play a role in situational factors, including job and position redesigning, information sharing, stress management training, social support and assistance, technical support, job control and procedures, literacy facilitation, and engagement facilitation (Burke, 1993; Davis & Gibson, 1994; Jimmieson & Terry, 1998; Karasek, 1979; Li & Wang, 2021; Ragu-Nathan et al., 2008). Ragu-Nathan et al. (2008) and Li and Wang (2021) use these situational factors as inhibitors to control stress or pressure when working in an IT integration environment. So that when a person is faced with changing working conditions due to IT integration, these inhibitors can control the stress that may occur due to the work pressure that arises.

Other studies review a similar phenomenon with the concept of organizational support in the same context. Eisenberger et al. (1986) formulated this construct to capture individual perceptions of organizational treatment that can affect one's commitment to maintaining personal productivity, better attachment and performance, and acceptance of work challenges. In this case, the teacher assesses the school regarding the extent to which the school supports teachers in migrating learning to online learning. Perceived organizational support indicates to what extent a person believes that the organization where they work appreciates and considers them valuable so that they need to be given support to carry out their work well (Baran et al., 2012; Eisenberger et al., 1986; Rhoades & Eisenberger, 2002; Wang & Shu, 2008). According to the need to shift in learning design to be fully online and the demands for mastery of TPACK as new knowledge, teachers need support to maintain their performance. This organizational support is necessary because this shift increases the complexity of the work that requires teachers to sacrifice more significant effort than usual (Eisenberger et al., 1986), such as updating pedagogic knowledge (TPACK), adjusting learning formats, preparing new media, and teaching materials, and implement it in actual learning activities (Li & Wang, 2021). Therefore, this study formulates the following hypotheses:

H1: Organizational support has a positive effect on TPACK.

H2: Organizational support has a positive effect on teacher performance.

H3: TPACK has a positive effect on teacher performance.

The organizational support construct in this study refers to the technostress inhibitor constructs used by the research of Li and Wang (2021). These stressor inhibitors are forms of assistance provided by institutions to assist teachers in utilizing IT in academic activities (Skaalvik & Skaalvik, 2017). These assists were found to reduce stress and improve teacher performance (Li & Wang, 2021; Skaalvik & Skaalvik, 2017). However, in this study, these supports are expected to help teachers master TPACK, which is specific knowledge in utilizing IT with new learning designs. This organizational support can help teachers sharpen their sensitivity to IT for learning activities. This is necessary because teachers currently have mastered the use of IT in general but are constrained by its use with specific goals such as teaching and learning activities (Sagala et al., 2021). Organizational support is analyzed with a second-order construct with three dimensions: literacy facilitation, technical support provision, and involvement facilitation (Li & Wang, 2021). Literacy facilitation refers to programs organized by institutions to share, train, and improve teacher knowledge regarding IT usage for teaching and learning activities (Li & Wang, 2021). Technical support provision refers to technical assistance institutions provide to assist teachers in using IT and overcoming various obstacles in using IT in teaching and learning activities (Li & Wang, 2021). Lastly, involvement facilitation refers to teacher involvement in IT integration phases, such as appreciation when using new technology, accepting teacher recommendations for system improvement, and engaging teachers to improve applications or design new strategies (Li & Wang, 2021).

TECHNOSTRESS

The phenomenon of technostress has emerged and has been long studied by information systems researchers (Ayyagari et al., 2011; Brod, 1984; Tarafdar et al., 2011). Due to the massive implementation of IT in all fields of work, the education sector cannot be separated from the phenomenon of technostress (Effiyanti & Sagala, 2018; Li & Wang, 2021; Penado Abilleira et al., 2021; Rolón, 2014). Technostress itself is a psychological response from IT users who show pressure and tension due to the use of IT in their productive activities (Brod, 1984). These responses arise due to various factors called stressors. Usually, these stressors occur due to changes in work patterns, such as academic work, which used to have minimal technological integration but now demands high-intensity use of information technology. Adopting new IT tools can increase workload, job uncertainty, and insecurity due to weak IT mastery, work-home conflicts, and continuous technological innovation (Ayyagari et al., 2011; Effiyanti & Sagala, 2018; Li & Wang, 2021; Ragu-Nathan et al., 2008; Tarafdar et al., 2011). These criteria are called technostress-forming stressors.

Furthermore, this technostress phenomenon has been researched extensively so that it can be controlled to reduce human costs for companies and maintain the mental health of employees due to this technological disruption (Marchiori et al., 2019; Ragu-Nathan et al., 2008; Salanova et al., 2013; Tarafdar et al., 2011). Ragu-Nathan et al. (2008) and Tarafdar et al. (2011) used the inhibitor construct as a technostress controller for employees. Li and Wang (2021) also used this construct to control technostress in teachers in universities. As explained earlier, this inhibitor construct has the same basis as the organizational support construct. Therefore, in this study, the inhibitor construct was used as a proxy for organizational support to measure the extent to which teachers believe that the institution considers their existence as an asset so that teachers are supported during the migration process for fully online learning during the COVID-19 pandemic. Organizational support as an inhibitor of technostress will be helpful for controlling stress that may arise among teachers due to mandatory demands to carry out learning in a fully online mode (Sagala et al., 2021). At the same time, organizational support will help teachers master new knowledge, where new knowledge will help teachers master IT in learning, which in turn will help teachers control stress that arises in their academic work (Effiyanti & Sagala, 2018; Li & Wang, 2021; Sagala et al., 2021; Sredojević et al., 2016). Therefore, this study hypothesizes that:

H4: Organizational support has a negative effect on technostress.

H5: TPACK has a negative effect on technostress.

H6: Technostress has a negative effect on teacher performance.

The shifting circumstances toward fully online learning demand teachers to learn new IT utilization techniques and increase the intensity of work using computers; this is called techno-overload (Effiyanti & Sagala, 2018; Li & Wang, 2021; Ragu-Nathan et al., 2008). Furthermore, because teachers need to learn and practice new teaching modes, teachers may perceive IT for learning as a complex application and make their work complex; this response is known as techno-complexity (Li & Wang, 2021; Ragu-Nathan et al. al., 2008). Furthermore, continuous changes in the use of technology and the increasing intensity of facing computers may make teachers feel attacked by technology and increase uncertainty in their work patterns; this condition is called techno-invasion and techno-uncertainty (Li & Wang, 2021; Ragu-Nathan et al., 2008). Finally, these complex demands may make the teacher reflect on their capacity. This process of reflection often results in insecurity about their work due to their inability to master IT and compete with other teachers who are more proficient in IT; this insecurity is called techno-insecurity (Effiyanti & Sagala, 2018; Li & Wang, 2021; Ragu-Nathan et al., 2008). The five dimensions are stressors that form technostress. This study measured those dimensions using second-order constructs as previously done by Ragu-Nathan et al. (2008). Furthermore, the technostress construct was then tested for its influence on teacher performance to test the hypothesis of this research (Figure 1).

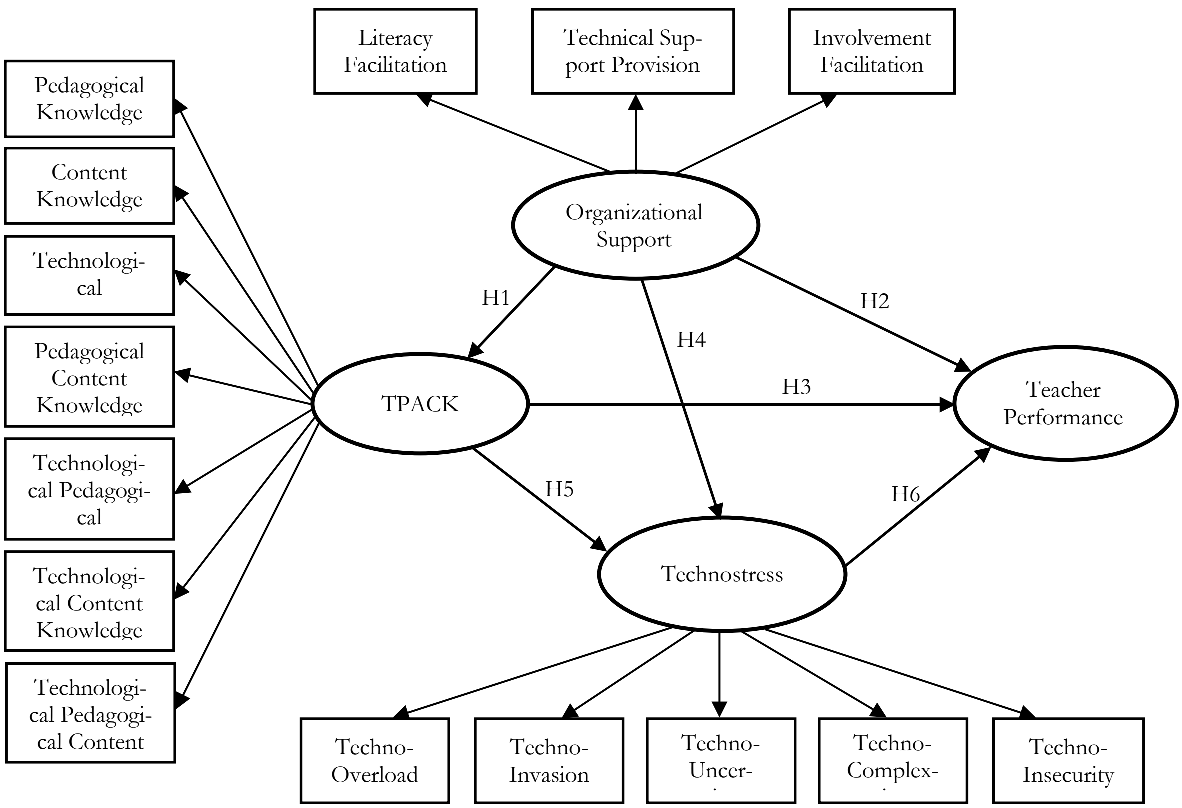

Figure 1. Research model

METHOD

RESEARCH INSTRUMENT

This research instrument was adapted from previous research. This study adopts the TPACK research construct from Schmidt et al. (2009) and Schmid et al. (2020), the organizational support construct was adapted from Marchiori et al. (2019), Fuglseth and Sørebø (2014), Ragu-Nathan et al. (2008), and Tarafdar et al. (2010), the Technostress construct from Li and Wang (2021), Fuglseth and Sørebø (2014), Ragu-Nathan et al. (2008), and Tarafdar et al. (2010), and the Work Performance construct from Tarafdar et al. (2010). These constructs were translated into Bahasa Indonesia and applied content validity by two experts. After that, the researcher also conducted face validity. Face validity is done by inviting four pre-service teachers to represent prospective respondents to review the questionnaire content. The purpose is to identify whether the prospective respondents have similar perceptions intended by the researcher regarding the questions or statements in the questionnaire. After obtaining input from experts and prospective respondents, the researchers made improvements, and the instrument was uploaded using a Google form so that respondents could access it easily. The questionnaire uses a 5-point Likert scale to obtain the data for the sample. The questionnaire contained 29 items to measure the TPACK construct, 13 items to measure the organizational support construct, 22 items to measure the technostress construct, and four items to measure the teacher work performance construct. TPACK itself contains seven dimensions, including pedagogical knowledge (PK), content knowledge (CK), technological knowledge (TK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPCK). Organizational support contains three dimensions, including literacy facilitation (LF), technical support provision (TSP), and involvement facilitation (IF). Technostress contains five dimensions, including techno-overload (TO), techno-invasion (TI), techno-complexity (TCx), techno-insecurity (TInsc), and techno-uncertainty (TU). The questionnaire items are in Appendix A. The outline of the variables' operational definitions is presented in Table 1.

Table 1. Variables and instruments sources

No	Variable	Operational definition	Sources
TPACK			
1	Pedagogical Knowledge	Pre-service teachers' knowledge of pedagogic aspects includes knowledge-related teaching plans, teaching methods, models, learning styles and student characteristics, basic teaching skills, and assessment and evaluation methods.	Schmidt et al. (2009)
2	Content Knowledge	Pre-service teachers' knowledge of the content of teaching materials following their fields of expertise, including the conceptual framework and the improvement of its practice.	
3	Technological Knowledge	Pre-service teachers' knowledge of recent technologies includes using various technologies such as computers, digital cameras, mobile devices, and word and data processing software.	
4	Pedagogical Content Knowledge	Learning management knowledge refers to content or teaching materials. In this aspect, pre-service teachers can manage appropriate learning strategies according to the content they teach or have reasons based on teaching materials in developing learning strategies.	
5	Technological Pedagogical Knowledge	Technological knowledge to implement the chosen learning strategy. In this case, pre-service teachers can find out, select and use the technology they need for teaching.	
6	Technological Content Knowledge	Pre-service teachers' knowledge about how technology changes the context and content of teaching materials also updated teaching materials on an ongoing basis.	
7	Technological Pedagogical Content Knowledge	A complex interplay of pedagogic, content, and technological knowledge so that teachers can integrate all three in learning. By mastering this knowledge, pre-service teachers know to teach students by utilizing appropriate technology and pedagogical strategy, presenting up-to-date teaching materials, and optimizing learning activities with this knowledge mix.	

Organizational Support			
8	Literacy Facilitation	Knowledge-sharing services to facilitate teachers' use of IT in teaching activities. This service can occur informally in discussion forums, learning communities, classroom learning, or special service centers provided by campuses or schools.	Fuglseth and Sørebø (2014); Li and Wang (2021); Tarafdar et al. (2011)
9	Technical Support Provision	A service center specifically established to assist prospective teachers regarding technical issues in using e-learning, learning management systems, network technicalities, etc.	
10	Involvement Facilitation	Support, appreciation, and praise for using technology in learning activities. The form of gratitude can be given verbally or with specific incentives. For example, in on-campus learning in teaching practice-oriented technology-oriented teacher candidates can be appreciated with good grades.	
Technostress			
11	Techno-Overload	Perception of excessive workload due to the use of IT in fully online learning carried out during the COVID-19 pandemic. The increase in workload occurs due to the obligation of pre-service teachers to prepare hybrid teaching materials, online learning media, learning videos, etc.	Li and Wang (2021), Ragu-Nathan et al. (2008)
12	Techno-Invasion	Changes in work culture due to the use of technology make prospective teachers feel intimidated by technology. As a result, technology is perceived as a threat and a demand in work.	
13	Techno-Complexity	Complicated feelings due to the use of complex technology such as e-learning, learning management systems, making learning videos, and online platform exams.	
14	Techno-Insecurity	Insecurity, in this case, is the concern of pre-service teachers losing their jobs or job opportunities because they are probably replaced with IT or other teachers who are more familiar with information technology in learning.	
15	Techno-Uncertainty	The constantly changing, evolving, and innovating IT features require pre-service teachers to continue learning and adapting.	
Performance			
16	Work Performance	Pre-service teachers' perception of the fully online teaching and learning activities they have implemented during the internship program.	Li and Wang (2021)

DATA COLLECTION

The researcher used a survey method with a purposive sampling technique to collect the data (Cooper et al., 2006; Creswell, 2012; Sekaran & Bougie, 2021). The research subjects were pre-service teacher-students in the economics and business field. Pre-service teacher-students are teacher-students who have passed their internship program. The teacher-students are trained to be teachers in vocational high schools in economics and business. When the data was collected, they already had experience in teaching, mainly in an online environment. The targeted respondent is considered representative in this research because the pre-service teacher-student has had actual teaching experience and organizational experience in their internship schools. The pre-service teacher-student is also expected to provide an objective response to their teaching experience because they are free from social desirability bias (Ashton & Kramer, 1980; Fisher, 1993). Social desirability bias is the tendency of the response given to meet the expectations of certain parties, for example, stakeholders or school as employer. That purpose is reasonable because students do not yet have an attachment to the school, so their opinions tend to be more objective than the teachers of the school itself (Ashton & Kramer, 1980). In addition, this study used an anonymous questionnaire to maintain the objectivity of the respondent's data.

Students with the criteria described above are in the seventh semester at the State University of Medan, Indonesia. Data collection was carried out using electronic questionnaires distributed through the head of the class (Cooper et al., 2006). Preservice-teacher student is not mandatory to participate in the survey. They were given the freedom to participate or not in the survey. Besides, the questionnaire is designed as anonymous to control their independencies when filling out the questionnaire. From 12 classes of teacher education study programs at the Faculty of Economics, State University of Medan, researchers collected 419 data for analysis. The demographics of the sample can be seen in Table 2.

Table 2. Demography of sample

No.	Variable		n	%
1	Gender	Male	64	15,24%
		Female	355	84,76%
		Sum	419	100%
2	Age	18	26	6,21%
		19	115	27,44%
		20	130	31,02%
		21	148	35,32%
		Sum	419	100%
4	Department	Administration Education	52	12,42%
		Accounting Education	92	21,95%
		Business Education	104	24,82%
		Economics Education	171	40,81%
		Sum	419	100%

The demographics of the sample show that women dominate the respondents. That composition is natural because women dominate the population of teacher-students at Medan State University. Furthermore, although the respondent's criteria are students who have completed the internship program, there is a wide age range among respondents, namely from 18 to 21 years of age. However, most of the participants are between 19 and 21 years old. This age range is very reasonable for 7th-semester students. Furthermore, the sample demographics also show that the researchers managed to get a representative sample from all teaching departments in the Faculty of Economics. The distribution of sample representation does seem uneven, but the weight of each representative is significant enough to represent the population in each department.

RESULTS AND DISCUSSION

DESCRIPTIVE STATISTICS

This study uses the 5-point Likert scale to measure the phenomenon. Therefore, the data is scaled from 1 as most dissatisfactory to 5 as most satisfactory. In descriptive statistics, the data is analyzed using the mean to understand the center of response, and standard deviation to understand the data variation for each dimension. Descriptive statistics in this study indicate that, in general, the dimensions that make up the TPACK indicate that prospective teachers have a moderate perception of mastery of TPACK with a range of 3.62-3.85. The TPACK dimensions also show a reasonably good data variation between 0.743-0.937. This value is slightly above the median value but has not entered the high category. The highest perception of mastery is on the Technological Pedagogical Knowledge variable, while the lowest perception of knowledge is on the Technological Knowledge variable. This condition is not statistically satisfactory. However, suppose we reflect on the limitations of the literature related to IT integration in fully online learning and the limitations of discussion about it in the classroom, then the profile is quite good and has the potential to be improved.

Furthermore, the response to organizational support shows a moderate number as well. Literacy facilitation has a mean score of 3.86 and a standard deviation of 0.893, Technical Support Provision has a mean of 3.71 and a standard deviation of 0.926, and Involvement Facilitation has a mean score of 3.87 and a standard deviation of 0.974. The value is the same with mastery of TPACK. This condition is not high but has the potential to be developed further. Even though schools may not have excellent technical support, they have been perceptions indicating there is support for prospective teachers to study technology for learning. This support can occur in classroom learning, in community or student study groups, mentoring in apprenticeship schools, and technical services provided by campuses or schools. However, further investigations related to this support must be studied further.

The technostress response of the sample is below both the TPACK mastery response and the organizational support response, which is in the range of 3.12-3.49, and the standard deviation is between 0.870-1.194. The standard deviation profile indicates that the teacher has a varied technostress response gap. This technostress profile cannot be underestimated as a threat variable. The trend of technostress experienced by teachers is still above the median value, which indicates that respondents tend to perceive technostress rather than not being disturbed by the demands of using IT. Researchers argue that teachers are still very likely to feel threatened due to IT integration in their teaching assignments. Likewise, the perception of teacher performance shows a reasonably high response, which is 3.91 on average. In addition, this variable also indicates a relatively low deviation rate, namely 0.797. The value indicates that the variation in the data is slightly near between one respondent and another (Table 3).

Table 3. Descriptive statistics

No	Variable	Avg	Std Dev
TPACK			
1	Pedagogical Knowledge	3,79	0,816
2	Content Knowledge	3,77	0,805
3	Technological Knowledge	3,62	0,937
4	Pedagogical Content Knowledge	3,69	0,743
5	Technological Pedagogical Knowledge	3,85	0,757
6	Technological Content Knowledge	3,74	0,816
7	Technological Pedagogical Content Knowledge	3,76	0,774
Organizational Support			
13	Literacy Facilitation	3,86	0,893
14	Technical Support Provision	3,71	0,926
15	Involvement Facilitation	3,87	0,974
	Technostress		
8	Techno-Overload	3,46	1,064
9	Techno-Invasion	3,19	1,172
10	Techno-Complexity	3,26	1,039
11	Techno-Insecurity	3,12	1,194
12	Techno-Uncertainty	3,49	0,870
Performance			
16	Work Performance	3,91	0,797

VALIDITY AND RELIABILITY TEST

This study analyzes construct validity through three steps, including convergent validity, discriminant validity, and reliability tests (Hair et al., 2009). First, convergent validity was carried out by observing the loading factor value and dropping the item with a loading factor of <0.6 (Hair et al., 2009). With these criteria, this study excluded one item from the Techno-Insecurity dimension in the technostress construct, namely the TIsc3 item. Meanwhile, the other items used have met the requirements of convergent validity. The cross-loading table is presented in Appendix B.

Second, the discriminant validity test used the Fornell-Larcker criteria (Fornell & Larcker, 1981). The Fornell-Larcker measure is carried out by reviewing the root of the AVE value entered into the correlation matrix diagonally, and discriminant validity is approved if the correlation value between variables in the correlation matrix is smaller than the root of AVE above it (Fornell & Larcker, 1981; Hair et al., 2009). This situation indicates that each construct is not identical to the other constructs. The value of the root of AVE is observable in the table in Appendix C on the top of each correlation coefficient of each construct in the correlation matrix. Based on the data in the table (Appendix C), the root of AVE has a greater value than every coefficient of correlation that existed under it in the matrix. Therefore, the constructs in this study have met discriminant validity.

Finally, the reliability test was observed by two criteria, namely Cronbach's alpha, and composite reliability, with a critical value >0.8 for both indicators of the test tool (Hair et al., 2009). Based on the data shown in Appendix A, all constructs in this study have met the reliability criteria. Therefore, with the fulfillment of those three criteria, this research can be continued at the second-order factor analysis stage (Table 4).

Table 4. Second-order factor analysis

No.	Second-Order Factor	Loading Factor
Organizational Support		
1	Literacy Facilitation	0,882
2	Technical Support Provision	0,911
3	Involvement Facilitation	0,903
Technostress		
4	Techno-Overload	0,905
5	Techno-Invasion	0,839
6	Techno-Complexity	0,933
7	Techno-Insecurity	0,825
8	Techno Uncertainty	0,635
TPACK		
9	Pedagogical Knowledge	0,850
10	Content Knowledge	0,849
11	Technological Knowledge	0,810
12	Pedagogical Content Knowledge	0,886
13	Technological Pedagogical Knowledge	0,888
14	Technological Content Knowledge	0,912
15	Technological Pedagogical Content Knowledge	0,909

Second-Order Factor Analysis

Researchers used second-order factor analysis to analyze whether the dimensions of the TPACK construct, organizational support, and technostress were decisive in shaping the construct (Rindskopf & Rose, 1988). This study extracts the three variables into a large construct because of the parsimony principle. Researchers avoid using too many variables to measure the effect of complex variables. Therefore, researchers can only examine the primary constructs' effect by utilizing second-order factor analysis. In this case, the researcher uses Confirmatory Factor Analysis (CFA) because the dimensions and constructs used are constructs that have been developed by previous researchers so researchers only confirm the use of these constructs in the new research model (Hair et al., 2009; Rindskopf & Rose, 1988). Testing the coefficients on the construct-forming dimensions in second-order factor analysis can be treated as loading factors in ordinary factor analysis (Rindskopf & Rose, 1988). This study uses <0.6 as the critical value of the loading factor, and the test results can be observed in Table 4 (Hair et al., 2009). The second-order factor analysis test results show that the techno-uncertainty dimension is the weakest dimension with a loading factor of 0.635. Meanwhile, other dimensions of the overall construct have excellent numbers with a loading factor value of >0.8. Thus, all dimensions represent the primary constructs.

Hypothesis Testing and Discussion

The researcher tested the hypotheses using variance-based Structural Equational Modeling (SEM) or PLS-SEM (Partial Least Square-SEM). The use of PLS-SEM was chosen due to sample issues and model complexity. Researchers consider the sample to be relatively small, referring to the complexity of the model with many items to be analyzed. Therefore the PLS-SEM would be more appropriate for explaining the proposed structural model than the covariance-based SEM (Hair et al., 2019). In addition, PLS-SEM also has good statistical power even though it was carried out in confirmatory studies (Hair et al., 2009, 2019). Thus, the use of PLS-SEM is considered more suitable in this study. The coefficient significance indicator from this data analysis is t-stat >1.96 (Hair et al., 2009). The results of the structural model test are presented in Table 5.

Table 5. Hypothesis testing

H	Path	Coef	t-stat	p-value	Result
H1	Organizational Support → TPACK	0,588	15,106	0,000	Supported
H2	Organizational Support → Work Performance	0,457	7,926	0,000	Supported
H3	TPACK → Technostress	0,353	7,738	0,000	Supported
H4	Organizational Support → Technostress	0,219	3,126	0,002	Not-Supported
H5	TPACK → Technostress	0,234	3,560	0,000	Not-Supported
H6	Technostress → Work Performance	0,021	0,560	0,576	Not-Supported

Based on the results of the PLS-SEM test, the researchers found that organizational support had a positive and significant effect on TPACK (r = 0.588, t-stat = 15.106); thus, H1 is supported. This finding reinforces the technology investment framework proposed by the OECD (2000). In this framework, the OECD argues that technology investment cannot be carried out without being followed by investment in human resources and policies to support the growth of these human resources. This finding also confirms the views of Adarkwah (2021), Bao (2020), Christensen and Knezek (2017b), and Daniel (2020), which indicate that teachers need sufficient knowledge to be ready to implement online learning. In the same context, Effiyanti and Sagala (2018) recommend professional teacher training so that teachers have computer skills and can compromise with the challenges of this digital era. This study found evidence that organizational support is essential for helping teachers master new pedagogical skills. However, as stated by Cochrane (2010), a teacher's expertise in using IT does not necessarily indicate that they can use IT for specific purposes in teaching. Teachers need technical facilitation and a sense of engagement that helps them connect specific pedagogical needs with specific IT needs to deliver certain knowledge content (Figure 2). This finding corrects the research of Li and Wang (2021), which has not considered the aspect of knowledge as a variable that bridges the teacher's performance in teaching students through the use of IT.

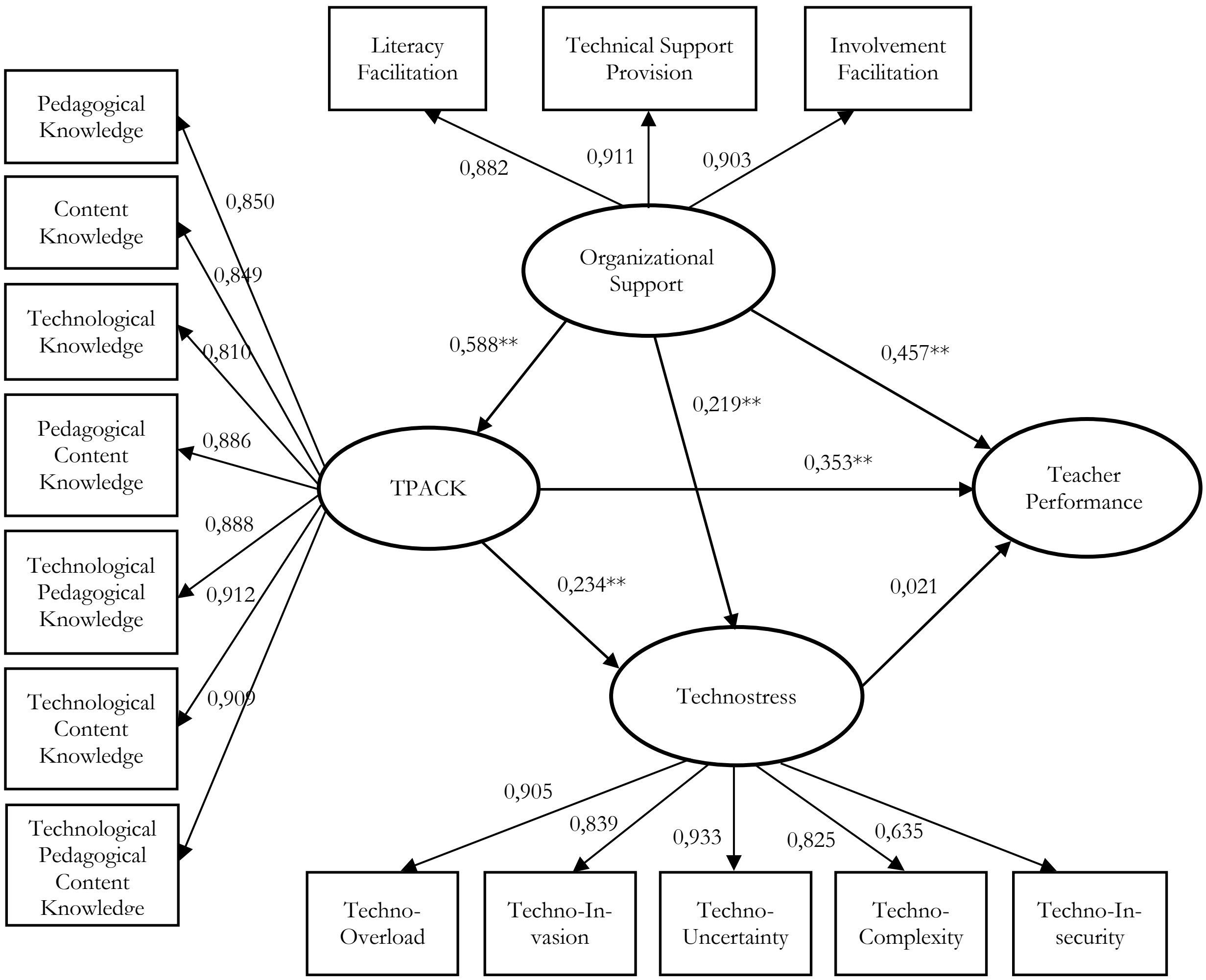

Figure 2. Result of structural model analysis

This study also found that organizational support and TPACK had a positive and significant effect on work performance (r = 0.457, t = 7.926; r = 0.353, t = 7.738). These findings support H2 and H3. According to endogenous theory, IT investment does not necessarily result in better individual or organizational performance (Sredojević et al., 2016). The findings of this study support this view by proposing two key variables, namely organizational support, and knowledge in producing teacher performance in IT-integrated learning or online learning. These two variables are very relevant to the indicators of IT investment success proposed in the endogenous theory framework (Sredojević et al., 2016) and the new economic framework (Grant, 1996; OECD, 2000; Rebelo, 1998). Specifically, in education, experts argue that TPACK is a key instrument for teachers to be ready and successful in implementing learning in this IT era (P. Mishra & Koehler, 2006; Niess, 2011; Schmidt et al., 2009). The results of this study provide empirical justification for this view with the TPACK value that positively and significantly affects teacher performance. With TPACK, teachers can master certain pedagogic needs so that students can engage in IT-mediated learning, which helps them master certain content of teaching materials (Koehler & Mishra, 2009; P. Mishra & Koehler, 2006). Referring to the results of other studies, this study complements the findings of Li and Wang (2021) and Ragu-Nathan et al. (2008) who previously found that these technostress inhibitors or in this study were reviewed as dimensions of organizational support affecting positive performance on IT-mediated jobs. Referring to the coefficient owned by each endogenous variable, it appears that the coefficient owned by organizational support is higher than TPACK itself. This finding indicates that organizational support is a key antecedent in producing optimal teacher performance in online learning, either by adding TPACK knowledge or directly to teacher performance.

Furthermore, this study found that organizational support and TPACK had a significant positive effect on technostress ($r = 0.219$, $t = 3.126$; $r = 0.234$, $t = 3.560$). Thus, H4 and H5 are not supported. This finding is unique because instead of reducing technostress, organizational support and TPACK increase technostress in teachers. This phenomenon may be explained by presenteeism on the use of IT in work (Ayyagari et al., 2011). In this case, Ayyagari et al. (2011) interpret presenteeism as the possibility of a person's accessibility to their work due to the use of IT. As has happened in online learning, especially during the COVID-19 pandemic, the use of IT or the full implementation of online learning is done to provide access to learning for students. Simultaneously, this access certainly opens equal access to teachers regarding their academic work. This access will provide an opportunity to exceed work time limits, discussion rooms, or other academic services that teachers provide through various possible devices, such as email, LMS, social media, mobile phones, and laptops (McGee, 1996). In addition, this data collection was carried out when there was a massive shift in educational and teaching practices due to the COVID-19 pandemic. Even though pre-service teachers had a lot of interaction with IT in their learning activity in the classroom, its use in a massive intensity and fully mediated by IT during the COVID-19 pandemic was something new for them. That new way of teaching and learning can put pressure on student teachers because they must prepare various learning tools and new media and have to learn new applications (Ayyagari et al., 2011; Daniel, 2020; Sagala et al., 2021). In new IT implementations and ongoing IT developments, the stress response is a reasonable response demonstrated by IT users (Arnetz, 1997; Ayyagari et al., 2011; Johansson, 1989; Korunka et al., 1995). Instead of reducing stress, organizational support opens a new understanding of how technology develops in education and the new complexities it will face. The teacher also realizes that the new knowledge demands are increasing and needed. In such circumstances, the teacher does not choose to avoid their work responsibilities. Therefore, the perceived stress is thought to increase because of unavoidable demands.

Finally, technostress was found to not affect teacher performance ($r = 0.021$, $t = 0.560$). This finding also shows the uniqueness of this study because technostress was found to have no impact on teacher performance. Referring to the research findings of Li and Wang (2021), some of the stressor variables tested did show inconsistencies; for example, techno-overload positively affected teacher performance, while techno-uncertainty did not affect teacher performance. Penado Abilleira et al. (2021) also found the influence of technostress dimensions partially on teacher performance. In the context of teachers unfamiliar with the use of IT in learning, technostress on lack of instruction and techno-inefficiency, which reduces teacher performance (Penado Abilleira et al., 2021). Meanwhile, for teachers who are accustomed to using IT in learning, it is found that IT misfits with needs that cause a decrease in performance (Penado Abilleira et al., 2021). Although, in research conducted in the business sector, technostress consistently has a negative impact on a person's performance (Ayyagari et al., 2011; Ragu-Nathan et al., 2008; Tarafdar et al., 2015). This uniqueness occurs presumably because of the teacher's working conditions and the teacher's unique characteristics. Teachers' working conditions during the COVID-19 pandemic have indeed placed IT integration as mandatory. Thus, even though teachers are under pressure when interacting with IT, it does not interfere with their optimal performance. On the other hand, the teacher's habit of using IT to prepare learning tools, teaching materials, and teaching media helped him compromise with full online learning, as Penado Abilleira et al. (2021) found. Thus, the technostress experienced by teachers due to changes in work patterns and the use of new IT is not enough to negatively affect their performance.

IMPLICATIONS

The results of this study have implications for managerial decision-making related to the management of teacher knowledge and expertise in implementing online learning. Educational institutions, schools, and universities should pay attention to providing teachers with access to new pedagogical knowledge, represented by mastery of TPACK. At the same time, schools or other educational institutions should ensure that teachers receive technical support, engagement, and literacy in various IT-mediated changes in learning practices. These two aspects can be implemented through teacher professional development programs, forming a technical assistance team, teacher assistance in the development of learning designs, teacher collaboration with the IT team, involving teachers in the development of applications and learning media, and various other strategic policies.

Furthermore, although technostress does not affect teacher performance, this phenomenon should still be controlled concerning mental health issues in the experience of technostress. Based on this study's results, technostress is challenging to manage as it exists by nature of the teacher's work environment. Additionally, the possibility of technostress experience is rising due to the continuous changing of IT that escalates the demands for learning innovations. Therefore, schools should have a compensation mechanism that targets social and financial aspects to control technostress among teachers. The accuracy of effective policies related to this issue certainly requires further research.

From the university's point of view, the current study's findings are helpful in refining the curricula of teacher training programs or teacher education programs and giving technical assistance to pre-service teachers. The teacher education and training program should update its curricula to construct TPACK as a standard in preservice teacher knowledge. The updated curricula may help the preservice teacher design more proper instruction for the online, blended, and hybrid teaching and learning environment. Furthermore, suppose those issues or materials have been discussed well in many courses and learning materials in the classroom, then pre-service teachers should gain more intense practical experience during internships. Practical experience should make teachers more agile in using their knowledge in dynamic circumstances. In the case of pre-service teachers doing practical experience in the internship program, universities should give technical or functional assistance in discussing their teaching problem, solving the problem with constructive discussion, and improving their performance. There are many activities that universities should do to assist the pre-service teachers' practical experience. First, is practical assistance regarding the content and pedagogical aspect. The pre-service teacher may obtain it from their supervisor lecturer. Second, is technical assistance regarding the technological aspect of teaching and learning activities. Technical assistance should be delivered by the supervisor lecturer, the school's LMS admin, and the university/faculty technical assistant according to the specific issue faced by the pre-service teacher. The point is that universities must take part in anticipating the massive impact of IT in teaching and learning activities by preparing preservice teachers with appropriate knowledge and skills.

CONCLUSION

This study found that (1) organizational support affects TPACK positively, (2) organizational support and TPACK affect teacher performance positively, (3) organizational support and TPACK affect technostress positively, and (4) Technostress does not affect teacher performance. Those findings are unique and bring insight into theoretical and practical aspects of IT disruption in the educational sector.

First, researchers found that organizational support and TPACK were valuable antecedents of teacher performance in an online environment, but simultaneously, technostress is not critical to threaten teacher performance. These findings show that teachers can maintain their job orientation and productivity even in the shock of shifting circumstances toward fully online learning. Teachers may believe they are responsible for running the instructional program to allow student learning even in uncertain conditions. Referring to Bandura's (1988) self-regulation, someone can accept the challenge and then set their strategy, goal, and action when they have self-regulation capability. However, technostress among teachers exists, and scholars still need to pay attention to that. Universities and schools should consider assuming that technostress impacts another side instead of teacher performance. Researchers argue that technostress will imply teachers' mental health if it is experienced constantly in the long term.

Second, technostress is uncontrollable by TPACK and organizational support. Practically, researchers argue it is an unavoidable circumstance. The educational system demands a rapid shift to fully online learning due to the COVID-19 pandemic. Therefore, it is mandatory for teachers to accept the challenge of maintaining the continuity of teaching and learning activities during pandemics. Therefore, researchers and policymakers should further analyze the precise impact of technostress among teachers. Understanding the negative impact of digital interaction during the productive task is crucial to determine appropriate strategies for maintaining a teacher's convenient work environment.

Third, theoretically, this study connects the concept of TPACK as knowledge to organizational support and technostress as the organizational and personal response to deal with massive IT integration in fully online learning during COVID-19 pandemics. This study bridges the educational conception of teacher competence to the behavioral framework of IS users to deal with the online environment. That approach is essential because teaching and learning is the task that engages human-to-human interaction, which is different from other productive activities like the business sector. This study explains how teachers respond to IT-integrated jobs in their academic activities. Current findings will give more wisdom to understand the threshold of IT usefulness in the educational field and the preference for managing it to maintain teachers' work quality. That uniqueness enriches the theoretical aspects of human-computer interaction and management information systems field.

Finally, this study recommends school leaders, policymakers, and stakeholders: (1) give attention to teachers' knowledge and provide organizational support to help them do their responsibility through excellent performance in an online environment – the dynamic of online learning results in the complex needs of instructional design, making teachers refine their design continuously; (2) develop a strategy to manage technostress among teachers from another aspect beyond TPACK and organizational support; and (3) develop a plan to compensate for teacher effort and sacrifices resulting from IT disruption in their working experience.

This study has a sample related to the teacher's field of study, which is limited to economics and business teachers. Further research can expand the sample variation to increase the generalizability of the research results. Analyzing the critical factors that effectively manage teachers' technostress is also worth doing. A qualitative research method may be helpful in exploring teachers' complex responses regarding IT-integrated tasks. Confirming and refining the framework usually developed in the private and educational sectors is crucial to generating more theoretical and empirical understanding.

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Appendix A: Items of Research Instrument

QUESTIONNAIRE

The current instrument is a questionnaire on the use of information systems in learning. This questionnaire seeks to capture your perceptions regarding the experience of using information systems in your teaching assignments at school during the COVID-19 pandemic. Your willingness to fill out this questionnaire is not mandatory. In addition, this questionnaire is anonymous to maintain your independence in responding. Therefore, if you decide to participate in this survey, please fill out the following questionnaire according to your real perceptions and abilities regarding Information Technology (IT) and Information Systems (IS) integration in the teaching and learning activities you experience. Your honesty in giving responses will benefit the quality of this research data and the quality of decision-making in the future. We appreciate your willingness to be a respondent. Your participation has helped the development of knowledge and practice in education.

1. **Gender** : M/F
2. **Age** : a. 18 b. 19 c. 20 d. 21
3. **Department** : 1) Administration Education
   2) Accounting Education
   3) Business Education
   4) Economics Education

Technological Pedagogical Content Knowledge (TPACK)

Pedagogical Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
1.	PK1	I can adapt my teaching according to what students have and have not understood.
2.	PK2	I can adapt my teaching style to different students.
3.	PK3	I can use various learning models to manage the class.
4	PK4	I can assess student learning outcomes in various ways.
Content Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
5.	CK1	I have extensive knowledge in the field of science that I teach.
6.	CK2	I can give specific examples in the material I teach.
7.	CK3	I understand the basic theory and concepts of the material I teach.
8.	CK4	I understand the actual development of practice and theory in the field of science that I teach.
Technological Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
9.	TK1	I always keep up to date with new technology.
10.	TK2	I work and learn to use technology regularly.
11.	TK3	I know a lot of different technologies.
12.	TK4	I have technical skills in using technology.

Pedagogical Content Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
13.	PCK1	I know how to choose an effective teaching approach to guide students to think and learn in the subjects I teach.
14.	PCK2	I know how to develop assignments to stimulate students' critical thinking skills in the subjects I teach.
15.	PCK3	I know how to develop exercises that help students construct their knowledge of the subjects I teach.
16.	PCK4	I know how to evaluate student learning performance in the subjects I teach.
Technological Pedagogical Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
17.	TPK1	I can choose technologies that enhance my selected teaching approach.
18.	TPK2	I can choose technologies that help students to learn during the lesson.
19.	TPK3	I can adapt the use of technologies that I am learning about in different teaching and learning activities.
20.	TPK4	I think critically and carefully about how to use technology in my classroom.
Technological Content Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
21.	TCK1	I know why technological developments can change the context and content of my teaching materials.
22.	TCK2	I can explain what technologies are useful in research and content development in my area of expertise.
23.	TCK3	I know what new technologies are currently being developed related to my field of knowledge and expertise.
24.	TCK4	I know how to use technology to participate in research or knowledge development in my area of expertise.
Technological Pedagogical Content Knowledge Schmidt et al. (2009); Schmid et al. (2020)		
25.	TPCK1	I can combine the content, technology, and learning approaches that I got in class when I was in college.
26.	TPCK2	I can develop strategies that combine learning content, technology usage, and appropriate learning approaches to help my teaching activities.
27.	TPCK3	I can choose technologies that can improve the content accessibility of the subjects I teach.
28.	TPCK4	I can choose certain technologies to use in my classroom to improve the quality of what I teach, how I teach, and what students learn.
29.	TPCK5	I can teach with the right combination of subject matter, technology, and learning approach.

Organizational Support

Literacy Facilitation Marchiori et al. (2019); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
1.	LF1	Our school encourages knowledge sharing to help us use Information Technology effectively.
2.	LF2	Our school provides professional training to ensure we use Information Technology effectively.
3.	LF3	Our school creates a work team to increase the use of Information Technology.
4.	LF4	Our school provides clear documents to guide teachers in using Information Technology.
Technical Support Provision Marchiori et al. (2019); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
5.	TSP1	The IT admin at our school works well in answering problems using Information Technology.
6.	TSP2	The IT admin in our school is a good worker and has good Information Technology knowledge.
7.	TSP3	The IT admin at our school is easy to meet.
8.	TSP4	The IT admin at our school is always ready and responsive in helping us.
Involvement Facilitation Marchiori et al. (2019); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
9.	IF1	We are given an appreciation if we use information systems and technology in doing assignments, presentations, or teaching practices.
10.	IF2	We always consult before using a new app.
11.	IF3	We are involved in improving applications or information systems on campus.
12.	IF4	We are involved in improving the way of information systems usage.
13.	IF5	We are always encouraged to use new applications or information systems to improve our teaching

Technostress

Techno-overload Li & Wang (2021); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
1.	TO1	Due to information technology, I have to do more tasks until it is not handled correctly.
2.	TO2	Due to information technology, I have to work with strict time limits.
3.	TO3	I have to change my work habits due to the use of information technology to improve the quality of teaching.
4.	TO4	I have more workloads because of the complexity of using information technology in teaching activities.

5.	TO5	I have little free time due to the use of information technology.
6.	TO6	Due to information technology, I even have to interact with my work on vacation.
7.	TO7	I have to work faster due to the use of information technology.
Techno-invasion Li & Wang (2021); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
8.	TIV1	I feel that I have to sacrifice my vacation time and weekends due to constantly interacting with information technology devices.
9.	TIV2	I feel that my personal life has been disturbed because of the use of information technology devices.
Techno-complexity Li & Wang (2021); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
10.	TC1	I often feel that the information technology tools used in teaching are too complex and difficult to understand.
11.	TC2	I often feel that the information technology tools used in teaching are too complex to be used effectively.
12.	TC3	Because of their complexity, I doubt that information technology tools can be of practical use in teaching practice.
13.	TC4	I do not have sufficient knowledge of information technology in terms of improving my performance in teaching.
14.	TC5	I have to sacrifice a lot of time and energy to learn the use of information technology in teaching activities.
Techno-Insecurity Li & Wang (2021); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
15.	TIS1	The use of information technology interrupts my work patterns.
16.	TIS2	I feel that my field of work is increasingly threatened due to the continuous development of information technology.
17.	TIS3	I have to continuously update my capabilities and expertise so that I will not be replaced by information technology one day or colleagues who have more information technology skills.
18.	TIS4	I feel threatened by other colleagues who are more tech-savvy.
19.	TIS5	I don’t want to share my expertise using information technology with my colleagues because I’m worried he will be replaced me one day.
Techno-Uncertainty Li & Wang (2021); Fuglseth and Sørebø (2014); Ragu-Nathan et al. (2008); Tarafdar et al. (2010)		
20.	TU1	There is a continuous improvement in information technology to increase its use in teaching and learning.
21.	TU2	There is a dynamic change to improve the application function of IS in education and teaching.
22.	TU3	Where I work, the school replaces ICT equipment regularly.

Work Performance

Work Performance Tarafdar et al. (2010)		
1.	WP1	The use of information technology in teaching and learning activities increases my productivity.
2.	WP2	The use of information technology in teaching and learning activities allows me to work anywhere.
3.	WP3	The use of information technology in teaching and learning activities allows me to do more things than usual.
4.	WP4	The use of information technology in teaching and learning activities allows me to try new ways of teaching.

Appendix B. Cross-Loading Factor (Convergent Validity)

Items	CK	IF	LF	PCK	PK	TSP	TCx	TU	TIsc	TI	TO	TCK	TK	TPCK	TPK	WP
CK1	0,881															
CK2	0,898															
CK3	0,854															
CK4	0,884															
IF1		0,822														
IF2		0,819														
IF3		0,852														
IF4		0,889														
IF5		0,785														
LF1			0,817													
LF2			0,864													
LF3			0,896													
LF4			0,887													
PCK1				0,838												
PCK2				0,903												
PCK3				0,899												
PCK4				0,875												
PK1					0,806											
PK2					0,787											
PK3					0,847											
PK4					0,852											
TCK1												0,833				
TCK2												0,885				
TCK3												0,894				
TCK4												0,879				
TCx1							0,869									
TCx2							0,855									
TCx3							0,867									
TCx4							0,810									
TCx5							0,841									
TI1										0,929						
TI2										0,931						

Items	CK	IF	LF	PCK	PK	TSP	TCx	TU	TIsc	TI	TO	TCK	TK	TPCK	TPK	WP
TIsc1									0,887							
TIsc2									0,877							
TIsc4									0,721							
TIsc5									0,794							
TK1													0,726			
TK2													0,899			
TK3													0,899			
TK4													0,881			
TO1											0,793					
TO2											0,813					
TO3											0,724					
TO4											0,834					
TO5											0,791					
TO6											0,759					
TO7											0,736					
TPCK1														0,856		
TPCK2														0,883		
TPCK3														0,874		
TPCK4														0,864		
TPCK5														0,848		
TPK1															0,887	
TPK2															0,899	
TPK3															0,877	
TPK4															0,819	
TSP1						0,869										
TSP2						0,870										
TSP3						0,878										
TSP4						0,889										
TU1								0,894								
TU2								0,898								
TU3								0,840								
WP1																0,895
WP2																0,911
WP3																0,881
WP4																0,900

APPENDIX C. DISCRIMINANT VALIDITY AND RELIABILITY

No.	Constructs	α	CR	AVE	CK	IF	LF	PCK	PK	TSP	TCx	TU	TIsc	TI	TO	TCK	TK	TPCK	TPK	WP
1	CK	0,902	0,932	0,773	0,879															
2	IF	0,890	0,919	0,696	0,496	0,834														
3	LF	0,889	0,923	0,751	0,428	0,672	0,867													
4	PCK	0,901	0,931	0,772	0,733	0,461	0,429	0,879												
5	PK	0,842	0,894	0,678	0,762	0,475	0,472	0,731	0,824											
6	TSP	0,900	0,930	0,769	0,408	0,730	0,736	0,437	0,453	0,877										
7	TCx	0,903	0,928	0,720	0,213	0,293	0,244	0,223	0,208	0,172	0,849									
8	TU	0,850	0,909	0,770	0,442	0,532	0,375	0,400	0,428	0,449	0,492	0,878								
9	TIsc	0,839	0,892	0,676	0,142	0,249	0,213	0,126	0,122	0,124	0,789	0,405	0,822							
10	TI	0,844	0,928	0,865	0,184	0,171	0,147	0,163	0,147	0,085	0,782	0,384	0,666	0,930						
11	TO	0,892	0,915	0,608	0,317	0,360	0,327	0,336	0,318	0,274	0,767	0,530	0,607	0,725	0,780					
12	TCK	0,896	0,927	0,762	0,672	0,518	0,486	0,780	0,701	0,495	0,241	0,431	0,178	0,213	0,388	0,873				
13	TK	0,873	0,915	0,730	0,640	0,434	0,470	0,612	0,658	0,455	0,183	0,446	0,176	0,161	0,324	0,730	0,854			
14	TPCK	0,916	0,937	0,748	0,720	0,534	0,425	0,770	0,727	0,447	0,254	0,501	0,150	0,217	0,382	0,838	0,658	0,865		
15	TPK	0,894	0,926	0,759	0,676	0,460	0,442	0,771	0,657	0,443	0,191	0,425	0,125	0,165	0,362	0,827	0,705	0,772	0,871	
16	WP	0,919	0,943	0,804	0,537	0,649	0,542	0,562	0,498	0,610	0,179	0,531	0,138	0,141	0,349	0,567	0,522	0,552	0,603	0,897

Note (*both for Appendix A and Appendix B*):

PK : Pedagogical Knowledge
CK : Content Knowledge
TK : Technological Knowledge
PCK : Pedagogical Content Knowledge
TPK : Technological Pedagogical Knowledge
TCK : Technological Content Knowledge
TPCK : Technological Pedagogical Content Knowledge
LF : Literacy Facilitation
TSP : Technical Support Provision
IF : Involvement Facilitation
TO : Techno-Overload
TI : Techno-Invasion
TCx : Techno-Complexity
TIsc : Techno-Insecurity
TU : Techno-Uncertainty

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STUDY FROM HOME! THE ANTECEDENTS AND CONSEQUENCES OF COLLABORATIVE LEARNING ON MALAYSIAN UNIVERSITY STUDENTS

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ABSTRACT

Aim/Purpose	Drawing on transactional distance theory (TDT) and collaborative learning, this research proposes a research model to examine the role of collaborative learning during the COVID-19 pandemic. It investigates the potential antecedents that influence students' academic achievements, autonomy, and satisfaction with online learning platforms.
Background	The coronavirus (COVID-19) epidemic devastating the world has shaken the global educational system; such a transformation compelled all educational institutes to utilize online learning platforms. Malaysian higher educational institutions were greatly concerned by this disease and faced considerable transformations that affected higher education learners. Additionally, the campus closure and movement regulations impacted traditional education. Thus, the Malaysian Government ordered students at higher education institutions to return to their hometowns and continue their studies through online learning. Therefore, online learning was the most reasonable alternative to resume the learning process. Furthermore, in the educational world, collaborative learning is pivotal

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to forming students' interpersonal skills. Collaborative learning practice is working in pairs or small groups to attain the learning objectives collaboratively. Collaborative learning refers to the process of acquiring knowledge in a collaborative setting as opposed to alone. Since the instructor and students are in separate locations, it is challenging for the teacher to facilitate collaborative learning.

Methodology This study utilized a quantitative method; purposive sampling was implemented, and the data were collected from 260 university students, both undergraduate and postgraduate, as long as they were affected by the COVID-19 pandemic in Malaysia.

The questionnaire for this research was designed to fit the research hypothesis. The items of the questionnaire have been adapted to certify the content's validity. The collected data were analyzed using Smart PLS software, which has been utilized as an essential data analysis tool.

Contribution This research contributes to: (1) a better understanding of the importance of communication and connection among students-students and teachers in online learning environments, as the results suggest that the more communication between students, teachers, and the environment itself, the greater the academic achievements, learners' autonomy, and satisfaction; and (2) the role of both collaborative learning and TDT on learners' academic achievements, autonomy, and satisfaction.

Findings This study advances by incorporating TDT and collaborative learning theories. This research model illustrates six main factors in online learning platforms that enhance students' academic achievements, autonomy, and satisfaction through collaborative learning. The results showed a strong association between TDT and collaborative learning regarding the online learning platforms' utilization for improving academic achievements, learners' autonomy, and satisfaction.

Recommendations for Practitioners This model provided exceptional support to students during this sudden switch to online alternatives and helped them cope with the considerable challenges they faced under the current circumstances. Moreover, this model provides a guideline for higher education teachers and administrators for coping with online learning platforms.

Recommendations for Researchers Drawing on the association between TDT and collaborative learning regarding the utilization of online learning platforms for improving academic achievements, learners' autonomy, and learner satisfaction, the research result presents a road map for researchers in the field of online learning. Accordingly, researchers are encouraged to utilize these theories, as they can lead to improvements among online learners in higher education institutions.

Impact on Society This preliminary model, which was developed throughout this research, will be a great support to both researchers and instructors to be able to utilize and elaborate in accordance with the role of online platforms on students' satisfaction, autonomy, and academic achievements. It is critical for higher education administrators to pay more attention to the nature of communication between students and student instructors, which has been shown to have a positive influence on their academic achievements, to implement online learning. Moreover, instructors and course developers must be trained and skilled to achieve online learning platform goals.

Future Research	Future research could include more information about blended learning environments and their relationship to the technology acceptance model as an online learning model. Researchers may extend the model used in this study.
Keywords	adult learning, collaborative learning, distance education, media in education, transactional distance learning theory, collaborative learning theory

INTRODUCTION

The coronavirus (COVID-19) has adversely affected the world's life sectors, including the educational system. The virus spread universally in such a short period that it led to highly critical and surprising economic, spiritual, social, psychological, and biological challenges (Tanhan, 2020). Additionally, the virus has resulted in significant challenges for numerous individuals, thus critically affecting university learners (Tanhan et al., 2020). Students at schools, colleges, and universities were directly affected by the COVID-19 epidemic. As a result of the shutdown of their educational institutions, most were unable to physically attend courses throughout the epidemic. According to scholars from various countries (Tanhan et al., 2020), university learners have been experiencing multiple challenges throughout the COVID-19 outbreak. For instance, a lack of information, skills, and equipment, an unstable internet connection, irrelevance, and challenges with system access were the obstacles faced by instructors and students during the COVID-19 epidemic. Nevertheless, it has offered opportunities and challenges to higher education institutions (Toquero, 2020). This surprising switch to online learning turned into an agility measurement of education institutions (Wu, 2020), with numerous education institutions focused on transferring the traditional education system to online learning. Additionally, this current digital transformation towards online platforms has been accelerated under the compulsory lockdown of many educational establishments due to COVID-19, and numerous educational organizations have begun to use different e-learning systems and tools. This demonstrates that technology use in teaching has gained more importance at all education levels.

Several factors determine the effectiveness of online learning, programs, and classes, for instance, student satisfaction, student autonomy, and students' academic achievements (Abdelkader et al., 2022). Nevertheless, designing and executing effective online environments is a complicated process involving many satisfaction factors, including teacher support, student autonomy, student collaboration, and communication (Zamakhsari & Ridzuan, 2015). Previous research has found a consistent link between student satisfaction and communication in online learning environments (Abdelkader et al., 2022; Zamakhsari & Ridzuan, 2015). Students' most popular online learning activities involve online group discussions, searching, quizzes, and online tests. Consequently, it is critical to improve student communication with their classmates and their instructor in online learning environments (Abuhassna et al., 2021; Abuhassna, Awae, et al., 2022; Zamakhsari & Ridzuan, 2015).

This current study investigates the role of online learning platforms on students' satisfaction, autonomy, and academic achievements during the COVID-19 pandemic in relation to their communications with their instructors and their classmates and their autonomy towards online learning platforms, and their influence on collaborative learning. Additionally, this study investigates the effects of the collaborative learning role on student-student communication, teacher-student communication, students' academic achievement, student satisfaction, and student autonomy. Because most educational institutions now offer online courses as an alternative to traditional classrooms, this study may have an impact not only on online courses but also on other educational institutions. This preliminary model, which was developed throughout this research, will be a great support to both researchers and instructors to be able to utilize and elaborate in accordance with the role of online platforms on students' satisfaction, autonomy, and academic achievements. Online learning advantages and applications have been discussed in earlier correlated literature (Abuhassna et al., 2020; Abuhassna & Yahaya, 2018; Wu, 2015).

Accordingly, this study's main problem lies in the fact that, although COVID-19 is likely to be a temporary crisis, it must nonetheless be a wake-up call for higher education institutions to be more open and flexible regarding online learning implementation and ensure more flexible educational delivery methods that serve various learner populations are provided (Martin & Furiv, 2020). The COVID-19 crisis offers global universities a real chance to get to grips with their addiction to flying staff around the world (Martin & Furiv, 2020). Thus, there is a need to develop a research model to locate significant evidence based on the data of students' interactions within online learning environments that influence their academic achievements, student autonomy, and satisfaction in collaborative learning environments. Consequently, this proposed model should be used as a guideline for both decision-makers and instructors in the industry of online learning regarding the implementation of online platforms to enhance the whole learning experience through these platforms. This study employs an online learning environment and a collaborative learning environment, bringing new and better foundations for the development of the distance learning system; that is, the study-from-home approach. Taking into consideration such conditions, our primary investigation was:

> In what way could this proposed model improve students' online learning regarding their academic achievements, autonomy, and satisfaction during the COVID-19 pandemic?

Drawing on the main question, this study aims to answer the following research questions:

1. What are the relationships between student-student communications, teacher-student communications, and collaborative learning?
2. What are the relationships between student-student communications, teacher-student communications through collaboration, and students' academic achievements?
3. What are the relationships between student-student communications, teacher-student communications through collaboration, and students' autonomy?
4. What are the relationships between student-student communications, teacher-student communications through collaboration, and student satisfaction?

LITERATURE REVIEW

During the COVID-19 pandemic, switching to distance and online learning resulted in inconsistencies in academic achievement among students (Muflih et al., 2021). Even though online learning addressed many complications caused by the lockdown, practical skills could hardly be delivered or trained via online platforms (Aslan, 2021). Online practical skills could be challenging for online learning (Paudel, 2021). Earlier studies showed conflicting conclusions on learning achievement levels during the COVID-19 epidemic in online learning settings. Academic achievements can significantly impact learning approaches, particularly in a pandemic of contextualized online learning (Coman et al., 2020). Nonetheless, students tended to evaluate online learning productivity negatively, refusing to participate in online learning and focusing on online environment issues (Wang et al., 2021). Several students negatively assessed online learning and have held negative attitudes regarding the efficiency of online learning. They neither thought they could achieve their education goals through online approaches nor considered that their communication skills could be improved through studying online (Coman et al., 2020).

Furthermore, students need to develop autonomy to learn online (Abuhassna et al., 2020; Moore, 2013; Moore & Kearsley, 2012). Student autonomy refers to the learner's ability to track their learning process. Acquiring the learning process with active involvement and self-autonomy is a prerequisite for online learning to be successful (Abuhassna et al., 2020; Abuhassna & Yahaya, 2018; Moore, 2013; Moore & Kearsley, 2012). It is recommended that instructors take responsibility for making students realize that they must become autonomous learners. In other words, the development of autonomy in each learner is intended to be objective in and of itself. This objective improves awareness that student autonomy in online learning should be incorporated into the curriculum (Abuhassna, Busalim, et al., 2022). Accordingly, this current study investigates the role of online learning platforms on learners' satisfaction, academic achievements, and students' autonomy during the COVID-19 pandemic, their interactions with their instructors and classmates, their autonomy towards online learning platforms, and their influence on collaborative learning. Additionally, this study investigates the effects of the collaborative learning role on student-student communication, teacher-student communication, students' academic achievement, student satisfaction, and student autonomy. This proposed model developed through this study will significantly aid scholars' and instructors' ability to elaborate and apply in accordance with the role of online environments on learners' satisfaction, autonomy, and academic achievements. Previous related research has discussed the benefits and applications of online learning environments (Abuhassna, Van, et al., 2022; Wu, 2015).

Therefore, this study's main problem lies in the fact that, although COVID-19 is likely to be a temporary crisis, it must be a wake-up call for institutions of higher education to be more open and flexible regarding online learning implementation and ensure providing more flexible educational delivery methods that serve various learner populations (Martin & Furiv, 2020). The COVID-19 crisis offers global universities a real chance to get to grips with their addiction to flying staff worldwide. As a result, there is a need to develop a research model to investigate the significant evidence based on student communication data within online learning settings that influence academic achievement and satisfaction in collaborative learning environments. Consequently, this proposed model should be used as a guideline for decision-makers and instructors in the online learning industry regarding online platform implementation to enhance the whole learning experience. Considering such conditions, this model provides a practical implication for future studies on how to improve students' online experiences through these study interventions.

THEORETICAL BACKGROUND

This study's theoretical framework has been built according to Moore's (2013) transactional distance theory (TDT) in addition to collaborative learning (CL).

Firstly, CL in university courses has its origins in the theories of behavioral learning, cognitive development, and social interdependence (Dahley, 1994). CL is a mature-centered education approach where learners themselves are reliable for education results and group control (Bruffee, 1984). Linda Harasim (2017) developed CL, a theory that focuses on Internet facilities to provide educational settings that promote knowledge-building and collaboration. Harasim explains CL as "a new learning theory that focuses on knowledge building, CL, and Internet use to reshape informal, non-formal, and formal education for the knowledge age" (p. 69).

Secondly, TDT has been chosen in the present study because the "TDT term refers to the physical distance between the instructor and the student" (Moore, 2013, p. 67). That depends on the learner's understanding, which occurs throughout the learner's communications with their classmates and instructor. Although the TDT origins could be traced to Dewey's work, it was Michael Moore who was recognized as the inventor of this theory, which was initially published in 1972. In his development and studies of this theory, he categorized three significant elements of TDT, which serve as the base for this theory. These elements are: (1) course design; (2) dialogue, or what this study refers to as "communications" (both student-to-student communication and teacher-to-student communication); and (3) learning autonomy. Yet this study focused on both TDT and CL theories and related them to CL and student satisfaction as the primary purpose of this study. TDT theory provides courses that differ in the desired autonomy degree based on course format and communication principles. Other theories relating aptitude and inspiration to work independently, such as self-determination theory (Deci & Ryan, 2012; Falloon, 2011) and self-directed learning (Garrison, 1997), are related to the autonomy concept. According to various studies, learning autonomy is critical for online learning (Abuhassna et al., 2020; Hung et al., 2010).

Hypotheses Development

This study's hypotheses were developed based on a combination of the different aspects of the two theories mentioned above. The first and second hypotheses were developed as a result of students' and teachers' communication and its relationship to collaborative learning.

H1: Students' and students' communications positively influence collaborative learning.

H2: Teachers' and students' communications positively influence collaborative learning.

Then, students' and teachers' communication and its relationship to students' academic achievement led to the formulation of the third and fourth hypotheses.

H3: Students' communications through collaborative learning have a positive influence on students' academic achievements.

H4: Teacher-student communications through collaborative learning positively influence students' academic achievements.

The fifth and sixth hypotheses were developed as a result of student-teacher communication and its relationship to student autonomy.

H5: Communication between students and between students through collaborative learning has a positive impact on students' autonomy.

H6: Teacher-student communications through collaborative learning have a positive impact on students' autonomy.

Finally, student-teacher communication and its relationship to students' autonomy led to the formulation of the seventh and eighth hypotheses.

H7: Students' communications through collaborative learning have a positive influence on students' satisfaction.

H8: Teacher-student communications through collaborative learning positively influence students' satisfaction. This demonstrates how these two theories work in parallel to improve this study's variables.

This proposed model explains how the theories of TDT, and the concept of CL can guide these components' roles and their relation to each other, thus making the online learning process more effective. In conclusion, this study employs TDT theory through collaborative learning to hypothesize and develop this study's hypothesis (see Figure 1).

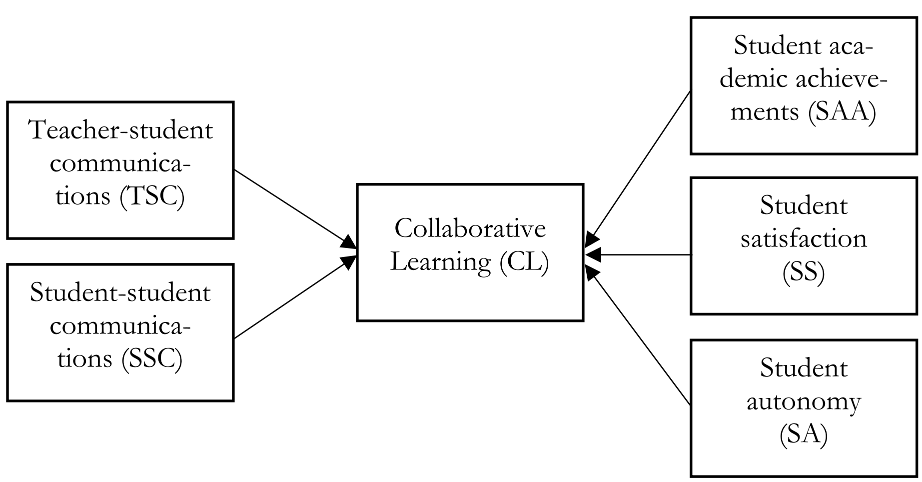

Figure 1. Conceptual framework

RESEARCH MODEL AND HYPOTHESIS

This section discusses the study's hypotheses and proposes the research model (see Figure.1). The research model for this study incorporates antecedents (i.e., student-to-student communications and teacher-to-student communications), collaborative learning factors, and consequences factors, including academic achievement, autonomy, and satisfaction. Thus, this study points to the following hypotheses.

Student-student and student-teacher communications and collaborative learning

Students' communications and collaborative learning in this study are referred to as their connections and feedback among themselves in online settings and how such communications could be enhanced using collaborative learning approaches. Collaborative learning offers social skills like teamwork, professionalism, problem-solving, critical thinking, cultural intelligence, and written and oral communication, which are crucial for future fieldwork in technology and science (Hollis & Eren, 2016). Additionally, collaborative learning is vital when responding and adapting to the new professional demands of drastically changing workplaces. Linton et al. (2014) determined that learners in group environments achieved considerably better conceptual understanding than students in courses with an individual environment. As Vygotsky (1978) suggested, this could be improved if learners were left in groups based on their proficiency and experience level. In this case, less proficient learners benefit from the communication skills of more capable learners. Thus, learners with a higher proficiency level benefit from others teaching their less capable peers. Furthermore, learners with varying levels of proficiency may benefit from the experience as a collaborative one. Communications among learners themselves allow them to improve and use their communication skills (Major, 2015). Prior research on collaborative online learning investigated how traditional collaborative learning features emerged in online learning environments. Collaborative learning characteristics, for example, purposeful design, unique collaboration, and meaningful learning are attempted differently during online meetings than in traditional face-to-face meetings (Barkley et al., 2014). Teacher-student communications and collaborative learning are defined in this study as their relationship and communication with their instructor on online platforms, and how such communications could be improved using collaborative learning approaches. Teacher support for students has been empirically examined, and the results indicate that the students' perceived teacher support influences their communications (Zhao & Qin, 2021). Besides, in online environments, teacher support is a personal feature that affects students' online learning. Several investigations have found that student-teacher support and communications positively correlate with online learning adoption (Lee et al., 2020). As a result, online instructors play an important role as a mediator in creating a constructive-cantered learning environment that can encourage collaboration and support the achievement of learning objectives (Rovai, 2004). Group work and activities in online settings need further modifications and factors beyond traditional face-to-face settings. Such a reality involves instructors considering alternate solutions to collaborate, clarify scripted guidelines, and communicate. For instance, Vonderwell and Turner (2005) stated that learners need practical and clear communication of online instruction and messages. Lack of interaction and delay in asynchronous communication are essential factors that need to be considered to avoid any negative impact on online learners (Kang & Im, 2005; Vonderwell & Turner, 2005).

H1: Students-students' communications have a positive influence on collaborative learning.

H2: Teacher-students' communications have a positive influence on collaborative learning.

Students-students' and teacher-students' communications, and students' academic achievements

Students' communications and students' academic achievements in this study describe their feedback and interactions among themselves on online platforms and how these communications can improve their academic achievements. In the education system, particularly online education, learners work hard to succeed in their future careers. For instance, in online education, learners require more effort to obtain higher grades, which ascertain their proficiency throughout their course. Students work hard for their academic performance throughout the lessons taught in any semester (McKenzie et al., 2004). In online learning platforms, students and their instructors are physically separated. Thus, their usage of technological resources fills this distance gap, and learners learning online are called distance learners (Casarotti et al., 2002). In this study, teacher-student communications and students' academic achievements describe how students' feedback and interaction among themselves in online settings can improve their academic performance. Furthermore, a study by Henke and Russum (2000) throughout their research suggested that individual separation could create a sense of inaccessibility among many learners. That is why they discovered the use of e-mails, website forums, and internet facilities to alleviate their feelings of isolation. The study suggests that social media and tutorial interaction could decrease student isolation. Additionally, learners and their instructors must be connected throughout the online learning process to overcome their isolation sense (Abuhassna, Awae, et al., 2022; Abuhassna & Yahaya, 2018).

> **H3:** Students-students' communications through collaborative learning have a positive influence on students' academic achievements

> **H4:** Teacher-students' communications through collaborative learning positively influence students' academic achievements.

Students-student communications and students' autonomy

Students' communications and autonomy in this study refer to their feedback and communication among themselves in online settings and how these communications could enhance their autonomy in online learning settings. Recently, researchers found that students' autonomy was predicted by online learning communication (Al-Tarawneh et al., 2021). Moreover, a study by Martin et al. (2021) has shown that students' autonomy is considerably correlated to achievement and dramatically facilitates the link between achievement and adaptability. Furthermore, studies have examined students' autonomy and teacher support with students' deep learning (Zhao & Qin, 2021) in online materials and contexts. The students need to gain the strategies and habits of studying, which will help them determine the learning steps and master their learning process. Online learning eliminates the temporal aspect of learning and teaching by providing continuous guidance and materials. However, the smooth access does not indicate the increasing amount of time students spend on their studies, as the lack of autonomy is noticeable. Non-temporality introduces the possibility of increased transactional distance, which becomes an impediment to the learning process (Martin et al., 2021).

> **H5:** Students-students' communications through collaborative learning have a positive influence on students' autonomy

> **H6**: Teacher-students' communications through collaborative learning have a positive influence on students' autonomy

Students-students' and teacher-students' communications and students' autonomy

In this study, students' communications and academic achievements imply their feedback and communication among themselves in online settings, as well as how these communications could improve their satisfaction in online learning settings. Satisfaction may be defined as a point factor of performance and expectation. Cultural differences impact the learner's satisfaction level with their perception of the services (Tian & Wang, 2010). An encouraging learning context could improve students' satisfaction and achievement through online learning. The learner's satisfaction level is the boundary between the anticipation level and the present findings. Learner satisfaction is the outcome of achievement, enjoyment, and thus, "a successful and pleasant experience" (Tian & Wang, 2010). Understanding learning satisfaction is important because it can provide the necessary point to improve learners' education (Khiat, 2013). Studies on learners' satisfaction with online learning platforms have gained a lot of interest and attention due to their impact on the educational effectiveness of instructional materials. As online learning courses are broadening, it is significant to study learners' satisfaction with such curriculums and how these affect their academic achievement and satisfaction. Teacher-student communications and students' autonomy in this study refer to their feedback and communication among themselves in online settings and how these communications could enhance their autonomy in online learning settings. Any student, whether they are enrolled in conventional or online learning, is required to possess the essential skill and capacity of autonomy. Both methods provide the issue of monitoring novel learning models, although the former is more prevalent. Learners have been encouraged to work toward becoming independent learners as an important component of online education for a long time (Alley, 2019; Cheon et al., 2012). Therefore, determining online learning autonomy has tremendous importance and presents challenges for establishments, educators, and students. Thus, teaching how to learn is not just in a classroom but also changing what is done. Communication between learners and instructors is essential in online learning environments (Jacobs et al., 2016). In this context, it is evident that creating students capable of reinforcing their learning is essential. However, what is the way to make this happen? The need to answer such a question is simply met by providing instant feedback from their instructor during online learning courses (Abuhassna et al., 2020). Teacher-student communications and students' academic achievements in this study refer to their feedback and communication among themselves in online settings and how these communications could enhance their satisfaction in these settings. Many identifications of the learner's satisfaction can determine the satisfaction level, for example, the learning environment, the course elements, interaction and communication elements, individual learner elements, the institution, and the faculty. At the same time, they discuss the details related to the instructor's role, the learner's attitude, the effectiveness of online environments, and social presence. To design and create the proper online learning courses or programs to meet the requirements and satisfaction of online learners, it is essential to examine the communications between the students and their instructors (Abuhassna, Van, et al., 2022; Jackson, 2014; Kardo, 2015). The kind of learners in the course may also be necessary, as some of them may not have the experience to compensate for the lack of face-to-face interaction with the tutor, mainly when they are registering for their first time in online programs. Many have concentrated on the associations between learner satisfaction with online programs and student experience or demographics with ICT and online education (Abou Naaj et al., 2012; Ryan, 2013).

> **H7:** Students-students' communications through collaborative learning have a positive influence on students' satisfaction

> **H8:** Teacher-students' communications through collaborative learning positively influence students' satisfaction.

RESEARCH METHOD

SURVEY INSTRUMENT

The questionnaire for this research was designed to fit the research hypotheses. Accordingly, the questionnaire was designed to measure Teacher-Student Communications (TSC), Students-Students Communications (SSC), Collaborative Learning (CL), Students Academic Achievements (SAA), Students Satisfaction (SS), and Students Autonomy (SA) through social media platforms. The items of the questionnaire have been adapted to certify the content's validity. Thus, this study's questionnaire was comprised of two major sections.

The first section included the respondents' demographic details, such as age, gender, and educational level. The second section (See Appendix) consisted of 35 items that were adapted from earlier studies as follows. Teacher-Students Communications and Students-Students Communications were taken from Abuhassna et al. (2021) and Bolliger and Inan (2012). Collaborative learning was measured using six adapted items (So & Brush, 2008). Eight items were adapted from Students' Academic

Achievements (Abuhassna et al., 2020). Six Student's Satisfaction items were adapted from Dziuban et al. (2007). Five Students' Autonomy items were adapted from Barnard et al. (2009) and Pintrich et al. (1991).

Sampling and Sample Size

While this study was being conducted, Malaysia's COVID-19 pandemic remained active. Due to the pandemic, the Malaysian Government, and the Ministry of Higher Education (MOH) ordered that those educational institutions, schools, and universities close their doors. Thus, all samples in this study were students affected by COVID-19 who were studying from home. The most important criterion for individual inclusion in the research is that "they are students that have actively been involved in online teaching during the COVID-19 pandemic." Both undergraduate and postgraduate students were involved in this study as one category since they both have been affected by the pandemic. Purposive sampling was implemented. Using purposive sampling, the authors of this study determine the significant characteristics of the people who would form the samples and reach the people who match these characteristics. Due to this criterion, the sample may also be considered within the scope of criterion sampling (Maxwell, 2012). The respondents' demographic collected data show that of the 260 respondents, 76 (29.2%) were males, 184 (70.7%) were females, 201 (77.3%) were in the age range of 24 years and above, 41 (15.7%) were in the age range of 21 to 23 years old, and 18 (6.9%) were in the age range of 18 to 20 years old. Regarding the level of study, 78 (30%) were in their first year of study, 100 (38.4%) were in their second year of study, 22 (8.4%) were in their third year of study, and 3 (1.1%) were in their fourth year of study, 12 (7.5%) were in their fifth year of study, and 45 (17.3%) did not select their level of study. The collected data were analyzed using Smart PLS software, which has been utilized as an essential data analysis tool. The Smart PLS utilization process includes two stages: first, evaluating construct validity and convergent validity, together with the discriminant validity of the measurements; and second, analyzing the structural model. The phases mentioned above are suggested by Hair et al. (2012).

data Collection and Analysis

The data collected in this research was mainly accumulated from undergraduate and postgraduate students at one Malaysian university. A combined total of 268 questionnaires were received. However, eight questionnaires have been excluded due to incomplete items. Consequently, the total number of valid questionnaires was 260 after this exclusion. Thus, the research was carried out with 260 students taught at different levels of education in other cities all over Malaysia. Such an exclusion step was supported by Hair et al. (2012). Furthermore, Venkatesh et al. (2012) noted that this method is vital to be carried out as the presence of outliers can cause biased results.

Results

Common Method Bias

Before examining the measurement model, we test the standard method for the collected sample. Using the Human Single Factor Test (Podsakoff et al., 2003), all constructs were loaded into a single factor. The result showed that the percentage of the explained variance by the single factor accounted for 34.19%, below the threshold value of 50% (Podsakoff et al., 2003). Thus, the data used in the study has no severe issues in terms of common method bias.

Measurement Model Assessment

The first step in the data analysis procedure is to examine the measurement model. Measurement model assessment tests the reliability and validity of the measurement items and their respective constructs. Internal consistency, convergent validity, and discriminant validity were examined (Hair et al., 2017). Two metrics were used to investigate the internal consistency: Cronbach's alpha and

Composite Reliability (CR). The value of Cronbach's alpha should exceed 0.7, and a CR value of 0.70 and above can be considered satisfactory (Hair et al., 2021). Concerning convergent validity, two metrics were applied: items' outer loading was 0.5 and above, and the average variance extracted (AVE) should exceed 0.5 (Hair et al., 2017). As shown in Table 1, the results on internal consistency show that Cronbach's alpha of all constructs exceeds 0.7 and the CR value of each construct exceeds the required value of 0.70. Furthermore, the convergent validity metrics show that the outer loading of all measurement items was above the threshold value (Table 1). Similar to the AVE value, all constructs have shown an AVE value more significant than the required value of 0.5. These results demonstrate that the model's constructs have high internal consistency and convergent validity (See Figure 2).

Table 1. Internal consistency and convergent validity results

Construct Name	Items	Outer loadings	Cronbach's Alpha	CR	AVE
Teacher- Students' Communications	TSC1	0.709	0.837	0.883	0.602
	TSC2	0.797			
	TSC3	0.799			
	TSC4	0.801			
	TSC5	0.768			
Students-Students Communications	SSC1	0.802	0.88	0.912	0.675
	SSC2	0.792			
	SSC3	0.843			
	SSC4	0.860			
	SSC5	0.810			
Collaborative Learning	CL1	0.765	0.883	0.911	0.631
	CL2	0.826			
	CL3	0.841			
	CL4	0.774			
	CL5	0.791			
	CL6	0.767			
Students' Academic Achievements	SAA1	0.622	0.897	0.918	0.586
	SAA2	0.703			
	SAA3	0.785			
	SAA4	0.647			
	SAA5	0.829			
	SAA6	0.850			
	SAA7	0.832			
	SAA8	0.818			
Students' Satisfaction.	SS1	0.788	0.837	0.876	0.542
	SS2	0.697			
	SS3	0.732			
	SS4	0.680			
	SS5	0.730			
	SS6	0.783			
Students' Autonomy	SA1	0.832	0.872	0.904	0.654
	SA2	0.865			
	SA3	0.713			
	SA4	0.807			
	SA5	0.819			

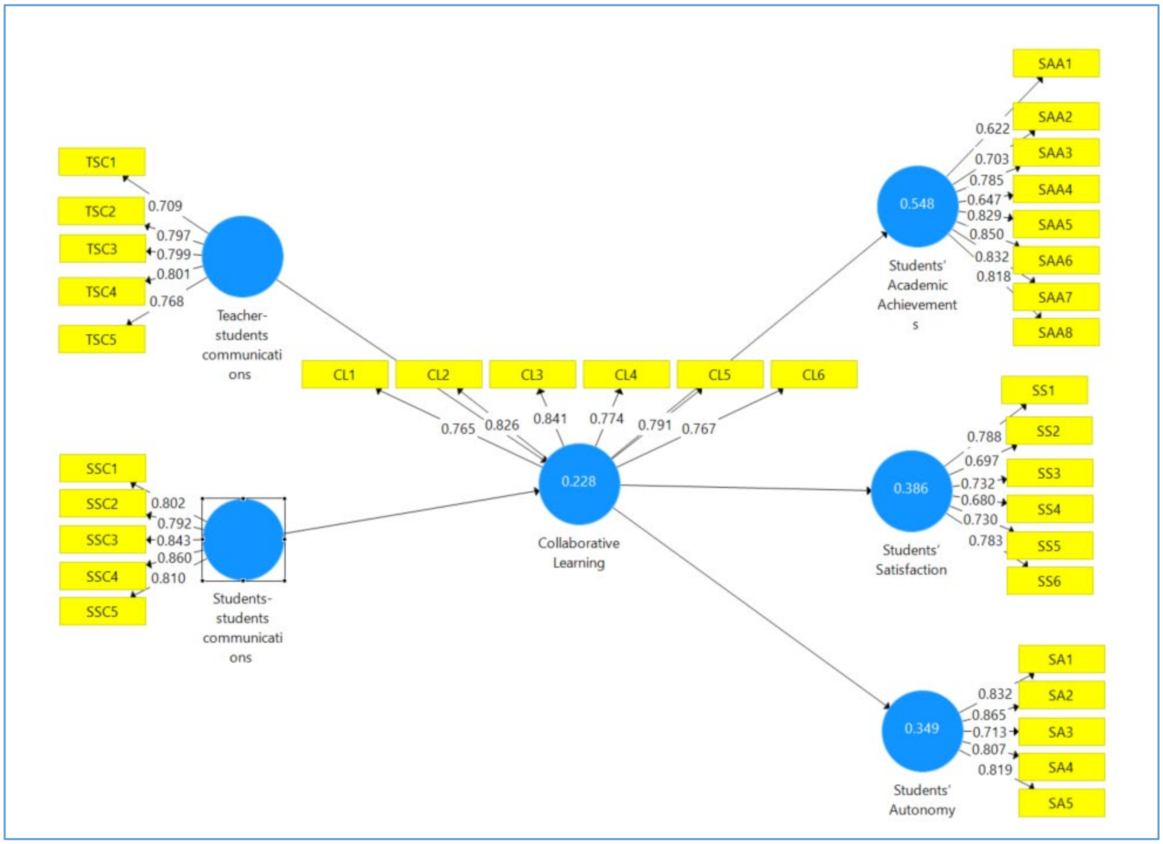

Figure 2. Items outer loadings

The discriminant validity was examined using the Fornell-Larcker criterion and the Heterotrait-Monotrait ratio (HTMT) (Hair et al., 2017). The first metric Fornell-Larcker criterion compares the value of the square root of AVE with all the constructs. The square root value of AVE for each construct should be greater than its correlation with the other constructs in the model (Hair et al., 2017). In this study, the result of the Fornell-Larcker criterion, as shown in Table 2, indicates that the AVE square root for each construct is greater than the highest correlation with any other construct. The second metric we used to examine discriminant validity is HTMT. According to Henseler et al. (2015), the HTMT value of each variable should not exceed 0.090. As shown in Table 3, all HTMT values are less than 0.90, thus indicating adequate discriminant validity.

Table 2. Fornell-Larcker criterion

Construct	CL	SSC	SAA	SA	SS	TSC
Collaborative Learning	**0.795**					
Students-Students Communications	0.394	**0.822**				
Students' Academic Achievements	0.74	0.329	**0.770**			
Students' Autonomy	0.591	0.275	0.633	**0.809**		
Students' Satisfaction	0.621	0.313	0.651	0.643	**0.736**	
Teacher-students communications	0.386	0.336	0.526	0.35	0.452	**0.776**

Table 3. Heterotrait-Monotrait ratio (HTMT)

Construct	CL	SSC	SAA	SA	SS	TSC
Collaborative Learning						
Students-Students Communications	0.441					
Students' Academic Achievements	0.825	0.389				
Students' Autonomy	0.625	0.32	0.649			
Students' Satisfaction	0.677	0.363	0.683	0.701		
Teacher-Students communications	0.428	0.399	0.602	0.378	0.524	

Structural Model Assessment

Following the measurement model assessment, we performed the structural model assessment to test the variance explained (R^2) by the dependent variables and the path coefficient based on the proposed hypotheses. Based on Hair et al. (2017), we used the bootstrapping technique with 5,000 subsamples, two-tailed tests, and a 0.5 significant level to generate the standard error and t-statistics. The R2 values in Figure 2 reveal that the explained variance of collaborative learning, students' academic achievement, students' satisfaction, and students' autonomy is 22%, 54%, 38%, and 34% respectively, thus demonstrating satisfactory predictive power (Hair et al., 2017). Moreover, the path coefficient results in Table 4 show that the eight main paths are significant and have a positive effect. Students-students' communications have a significant impact on collaborative learning (β = 0.29, t = 4.464,), supporting H1. Furthermore, the findings revealed a significant positive effect of Teacher-Students communications on collaborative learning (β = 0.286, t = 3.936), supporting H2. Further, both student and teacher-student communications have indirect positive effects on students' academic achievements; through collaborative learning, the bootstrapping test showed a highly significant level of both indirect paths with β = 0.22, t = 4.436, and β = 0.212, t = 3.592, supporting H3 and H4 respectively. Student-student communication has an indirect positive effect on students' autonomy via collaborative learning (β = 0.176, t = 4.207), which supports H5. Similarly, teacher-student communication has an indirect positive effect on students' autonomy via collaborative learning (β = 0.169, t = 3.592), supporting H6. Furthermore, the findings revealed that both student-student and teacher-student communications have a positive indirect effect on students' satisfaction via collaborative learning (β = 0.185, t = 4.272, β = 0.178, t = 3.444), supporting H7 and H8.

In addition, the effect sizes (*f*2) and predictive relevance (Q2) of the independent variables were estimated. The *f*2 results, according to Hair et al. (2017) guideline, show that students-students communication has a medium effect on collaborative learning (*f*2 = 0.102), and teacher-student communication has a small effect on collaborative learning (*f*2 = 0.094). Moreover, collaborative learning has a large effect on students' academic achievements (*f*2 = 1.02), students' autonomy (*f*2 = 0.53), and students' satisfaction (*f*2 = 0.62). The results also revealed that the Q2 results of all dependent variables, collaborative learning (Q2 = 0.194), students' academic achievements (Q2 = 0.228), students' autonomy (Q2 = 0.122), and students' satisfaction (Q2 = 0.175), are above zero, which indicate the predictive relevance of the independent variables.

Table 4. Hypotheses results

Path (direct effect)	Original Sample (O)	T-value	P-values	Sig. Level	**Decision**
Students-Students Communications -> Collaborative Learning	0.297	4.470	0.00	***	Supported
Teacher-Students Communications -> Collaborative Learning	0.286	3.898	0.00	***	Supported
Path (indirect effect)					
Students-Students Communications -> Collaborative Learning -> Students' Academic Achievements	0.22	4.436	0.00	***	Supported
Teacher-Students Communications -> Collaborative Learning -> Students' Academic Achievements	0.212	3.592	0.00	***	Supported
Students-Students Communications -> Collaborative Learning -> Students' Autonomy	0.176	4.207	0.00	***	Supported
Teacher-Students Communications -> Collaborative Learning -> Students' Autonomy	0.169	3.592	0.00	***	Supported
Students-Students Communications -> Collaborative Learning -> Students' Satisfaction	0.185	4.272	0.00	***	Supported
Teacher-Students Communications -> Collaborative Learning -> Students' Satisfaction	0.178	3.444	0.001	***	Supported

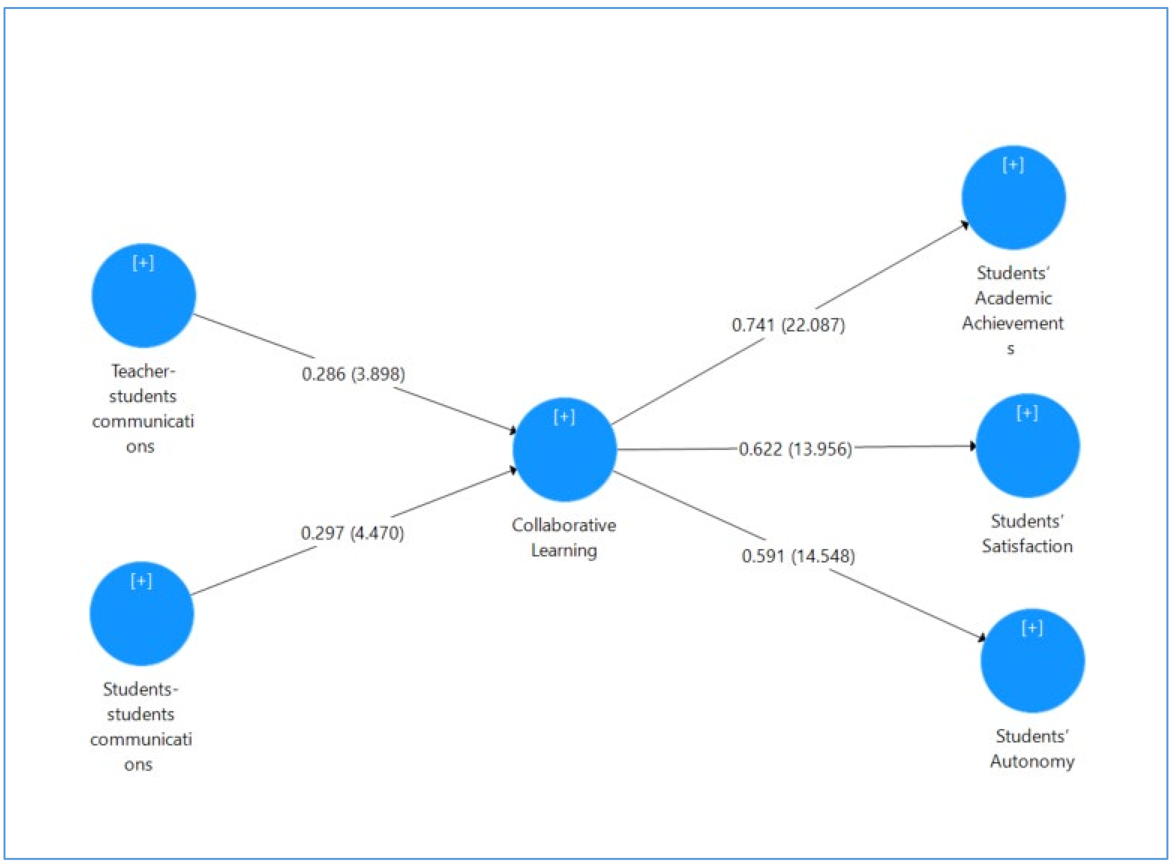

Figure 3. Path results

DISCUSSION

This study concentrated on answering the main question: "In what way could this proposed model improve students' online learning regarding their academic achievements, autonomy, and satisfaction during the COVID-19 pandemic?" Thus, to answer this question, this study investigated Hypotheses H1, H2, H3, H4, H5, H6, H7, and H8 illustrated in the proposed model (illustrated in Figure 1). Developing a new model through the combination of collaborative learning (CL) and transactional distance theory (TDT) was the main goal of answering this question by examining the critical factors towards employing online learning environments to enhance learners' academic achievements, student autonomy, and satisfaction in institutions of higher education during the COVID-19 pandemic. This study is taking a step forward by employing TDT and the CL theories. This research model illustrates eight main factors in online learning platforms that enhance students' academic achievements, autonomy, and satisfaction through collaborative learning. The results of this study showed a positive association between student communications and collaborative learning (H1), which indicates that putting the students through such an experience would enhance their collaboration among themselves and give them the capability to conquer any challenges that might arise when using online platforms. This agrees with some prior studies (Abuhassna, Busalim, et al., 2022; Barkley et al., 2014; Major, 2015; Moore & Kearsley, 2012). Furthermore, for H2, teacher-student communications and collaborative learning showed a significant and positive association (Hämäläinen & Vähäsantanen, 2011; Oncu & Cakir, 2011; Rovai, 2004), indicating the importance of communication between learners and their tutors during online learning sessions. Such findings are consistent with Hämäläinen and Vähäsantanen (2011).

Collaborative capability and perceived enjoyment are likely to be the most powerful causal factors influencing university students' adoption of social-media platforms for collaborative learning. Cooperative learning influences the academic achievements of students in universities, and active collaborative learning and engagement through social media enrich the learning activities of students and facilitate group discussions. Thus, their use should be encouraged in learning and teaching processes in higher education institutions. Moreover, in line with Vonderwell and Turner (2005), who examined preservice teachers' experiences and the meaning they gave to their experiences in a Technology Applications in Education online course, Kang and Im (2005) showed that factors related to instructional interaction predicted perceived learning achievement and satisfaction better than factors related to social interaction. However, social interaction, such as social intimacy, was found to have a negative impact on perceived learning achievement and satisfaction. In addition, Kai-Wai Chu and Kennedy (2011) reported and described the use of MediaWiki and Google Docs at the undergraduate level as online collaboration tools for co-constructing knowledge in group project work. Additionally, Xiong et al. (2015) concluded that the lack of interaction and delay factors in asynchronous online courses can influence learner learning negatively. Furthermore, students' communications and academic achievements demonstrated a significant and positive association (H3), revealing the learners' level of acceptance of online learning environments. This is consistent with Hussain (2013), Furnborough (2012), and Moore and Kearsley (2011), who stated that cooperation is a feeling that students share with their classmates and affects their response regarding their collaboration with their classmates. Additionally, teacher-student communications and students' academic achievements demonstrated a significant and positive association (H4), which specifies the primary role of the web-based platform in learners' academic achievements. This is consistent with Henke and Russum (2000), Kamal and Sultana (2000), Pillai (2011), Rwejuna (2008), and Shen (2004), who argued that the lack of online group work impedes the effectiveness of communication in online learning settings.

Additionally, the absence of subject knowledge and the language barriers prevent communication effectiveness in online learning environments. Furthermore, students' communications and students' autonomy showed a significant and positive association (H5), which shows that students need a sense of dependence on online environments, which is in line with Furnborough (2012) and Santos and Camara (2012). In contrast, Aldhafeeri and Male (2016) argue that students require aptitudes to investigate and combine information, recognize knowledge, and build meanings. Besides, teacher-student communications and students' autonomy demonstrated a significant and positive association (H6), which agrees with Jackson (2014), Jacobs et al. (2016), and Moore (2013), who indicated that the temporal and physical distance between educator and learner establishes an environment that must be taken into consideration psychologically and pedagogically as interactive relations are created within. Furthermore, determining online learning autonomy has great importance and challenges that revolve around institutions, educators, and students; thus, teaching how to learn is not only in a classroom but also changing what is done there. Therefore, communication between learners and instructors is essential in online learning environments. Additionally, student-student communications and satisfaction demonstrated a positive and significant association (H7), which indicates a level of acceptance by the students for adapting to online learning platforms. This agrees with Abou Naaj et al. (2012), Kardo (2015), Khiat (2013), Sinclaire (2011), and Tian and Wang (2010), who stated that learners' satisfaction in online settings is a statement of confidence in the system; furthermore, regardless of the environment used, the quality of the courses along with the connection with the learners themselves throughout the online learning sessions are very significant. Learner satisfaction is a primary need in the education process. Finally, teacher-student communications and student satisfaction demonstrated a positive and significant association (H8); these results are in line with Areti and Despina (2006); Biggs and Tang (2015); Thiagarajan and Jacobs (2001); and Trinidad and Pearson (2004). Furthermore, the findings of Abou Naaj et al. (2012), Jackson, 2014, Kardo, 2015, and Ryan (2013), claimed that online programs are often criticized for their low standard of dependability and less communication between instructors and students.

LIMITATIONS, RECOMMENDATIONS, AND FUTURE WORK

The limitations of this research must be put into consideration. The first possible limitation was the self-reported tools, which have some inherent limitations; more studies are required to investigate online learning platforms and their effectiveness toward students' academic achievement, satisfaction, and autonomy in online learning platforms. Secondly, the type of institution in the data collection process; the researcher conducted the study at one government university in Malaysia, so accordingly, the results from any other institution might vary. The voluntary nature of the participants is the second limitation of this study. Before participating in this research, students were told that participating in this experience was voluntary; any students who were unwilling to participate, unmotivated to participate, or unable to participate were summarily excluded from the results. Moreover, it must be acknowledged that because the course was taught online and developed independently by the instructors, there were differences in the structure, format, and requirements.

RECOMMENDATIONS FOR RESEARCHERS

For researchers, our findings contribute to the expanding body of knowledge on the integration of CL and TDT theories. During the COVID-19 epidemic, this research provides major empirical findings by studying the essential criteria for using online learning environments to improve students' academic achievements, autonomy, and satisfaction in higher education institutions. Moreover, this research emerges as the most influential factor in the adoption of online learning environments in teaching and learning. This finding demonstrates that online learning environments are a viable alternative to traditional classrooms. Nonetheless, this study offers significant insights into the design and implementation of successful online learning environments including several satisfaction criteria, such as instructor support, student autonomy, student participation, and communication (Abdelkader et al., 2022; Zamakhsari & Ridzuan, 2015). More theories are applicable in such a research field, for instance, the technology acceptance model (TAM). Future studies might integrate more information about blended learning settings and their relation to this model as an online learning model. Researchers may extend the model used in this study.

RECOMMENDATIONS FOR PRACTITIONERS

For practitioners, it is critical for higher education institution administrators to pay more attention to the nature of communication between students and student instructors, which has proven to have a positive influence on their academic achievements (Moore, 2013). Moreover, this proposed model provides a guideline for higher education teachers and administrators for coping with online learning platforms by underlining the integration of CL and TDT and the actions that need to be taken by all Malaysian universities to make their courses innovative and interesting for their students while studying online. Malaysian universities should also be considering the implementation of online teaching as a new method for teaching and learning in the future, not necessarily during pandemics but as an alternative approach; consequently, instructors and students must be ready and willing to utilize online learning during normal occasions. Moreover, instructors and course developers must be trained and skilled to achieve the goals of an online learning platform. Workshops and training sessions must be given to instructors and students to make them more familiar with and take advantage of such platforms.

CONCLUSION

In summary, this study connected TDT and CL theories that attach collaborative learning with students' satisfaction, academic achievement, and student autonomy. Based on the authors' knowledge, no other studies have collaborated on these two theories. The TDT and CL theories have been authenticated in the educational framework, presenting further understanding concerning learners' readiness and perspective on utilizing online learning platforms to enhance their satisfaction, academic achievement, and autonomy. The contribution of this study shows that further understanding of students' academic achievements, student satisfaction, and student autonomy needs to be introduced. This study highlights that the integration of CL and TDT has influenced this study's findings positively. In the case of traditional settings, students' communication through collaborative learning positively impacts their achievement, which is expected because students are used to such conventional classrooms. However, this study proved that even in the distance learning context, students' communication through collaborative learning positively influences their achievement, which is the primary purpose of the study by getting students to adopt such innovative settings as online learning.

This study has concluded that numerous educational institution administrators, for instance, online course designers, academic instructors, and users of online learning platforms, rationally consider learners' needs and demands. Implementation among users of online learning platforms could be generally simplified by this study's eight factors based on this model. As a result, this study suggests further research into the relationships between the complexity of online learning settings and the TAM as a theoretical approach to reasoned action with a role in online collaborative learning. This model postulates that users will accept a certain technology only when the factors that affect their decision to accept such a technology are already in place and influencing information technology behavior.

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LIST OF ABBREVIATIONS

TDT: Transactional Distance Theory
CL: Collaborative Learning
ICT: Information and Communications Technology
TSC: Teacher-Students Communications
SSC: Students-Students Communications
SAA: Students' Academic Achievements
SS: Student Satisfaction
SA: Students Autonomy
CR: Composite Reliability
AVE: Average Variance Extracted
HTMT: Heterotrait-Monotrait Ratio

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APPENDIX

STUDY QUESTIONNAIRE SECOND SECTION

Teacher-Students Communications (TSC)					
	Strongly disagree	**Dis-agree**	**Neu-tral**	**Agree**	**Strongly agree**
If I have an inquiry, my instructor will find time to answer.					
Instructor helps to identify problem areas in my study.					
Instructor gives me valuable feedback on my assignments.					
Instructor encourages me to participate in online sessions.					
It is easy for me to Communicate with my instructor online.					
Students-Students Communications (SSC)					
I work with my other colleagues' students					
I relate my work to my colleagues' work					
I share information with other students.					
I collaborate with other students online.					
We do group work as a part of our activities.					
Collaborative learning (CL)					
Collaborative learning experience in the computer-mediated communication environment is better than in a face-to-face learning environment.					
I felt part of a learning community in online learning sessions.					
I actively exchange my ideas with group members in online learning sessions.					
I am able to develop new skills and knowledge from other members in online sessions.					
I am able to develop problem solving skills through peer collaboration.					
Collaborative learning is effective in online learning classes.					
Students' Academic Achievements (SAA)					
Whenever I study online, all the necessary information will be provided for me (i.e., how to log in, how to end session).					
Whenever I study online, all instructions for using the materials will be provided (i.e., how to download materials, how to access links and videos).					
Whenever I study online, all discussion groups will be well organized (i.e., how to participate in a discussion, how to collaborate).					
Whenever I study online, grades will be returned in timely matters (i.e., I get grades immediately after I finish my quiz).					
I would take more online courses.					
I would recommend studying online to my colleagues.					

I consider studying online as an effective tool rather than face to face classes.					
I would enjoy my education more if all my classes were online.					
Students' Satisfaction (SS)					
I relate what I learn to my outside life of university.					
I always pursue topics that interest me.					
I connect my studies to my activities outside of class.					
I apply my everyday experiences in class.					
I am satisfied with online learning more than face to face classes.					
I can solve my own problems I face by reviewing the material provided online.					
Students' Autonomy (SA)					
I explore my own strategies for learning.					
I make my own decisions about my learning.					
I work during times I find convenient.					
I am in control of my learning.					
Online education is worth my time.					

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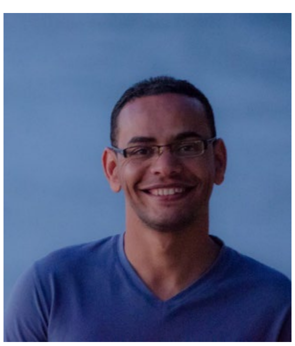

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INVESTIGATING FACTORS THAT AFFECT THE CONTINUANCE USE INTENTION AMONG THE HIGHER EDUCATION INSTITUTIONS' LEARNERS TOWARDS A GAMIFIED M-LEARNING APPLICATION

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ABSTRACT

Aim/Purpose	The main purpose of this study is to identify the factors affecting the continuance use intention of gamified m-learning applications by Higher Education Institution (HEI) learners in Malaysia.
Background	Mobile learning (m-learning) has been a popular choice among learners in HEIs due to its convenient 'on-the-go' concept. On the other hand, embedding gamification elements in m-learning applications help in increasing the users' interest in continuous use. Therefore, many HEIs have invested in producing their own m-learning products apart from utilizing existing m-learning applications that are widely available online. One of the challenges faced by HEIs is the low technology usage rates towards the 'in-house' developed applications, which affect the receptiveness of education stakeholders in investing or maintaining educational applications. Meanwhile, the lack of continuous usage had given a negative impact on their academic-related tasks and performance. Hence, it is important to understand the significant factors that influence learners' intentions in continuance usage of a gamified m-learning application. This will serve as an insight to the HEIs management regarding the needs and design that better suits their users' expectations.
Methodology	This study employed a correlational cross-sectional research design using an online survey. The participants of the final survey involved first-year students from one of the Malaysian public universities. For the final analysis, 269 responses were analysed using the partial least square-structural equation modelling (PLS-SEM) technique, which is a powerful multivariate analysis mechanism. The Expected Confirmation Model (ECM), which is a post-acceptance model, was extended with the pre-acceptance model named Extended Unified Theory of Acceptance and Use of Technology (UTAUT2), to form the research proposed model that describes the continuance intention in using a gamification-based m-learning application.
Contribution	This research contributes to the body of knowledge and helps better understand users' continuance intention in the post-acceptance phase of the gamified m-learning application. It exposes information at the individual level, regarding the continuance intention of using an m-learning tool that is equipped with gamification elements. This will mostly benefit the educational resource developers in the HEIs in producing effective 'in-house' learning tools.
Findings	This research develops a theoretical enhancement of the Expectation Confirmation Model (ECM) that affects the HEIs' m-learning resource developers and management, dealing with IT-related behaviour. Moreover, a solid continuance usage intention conceptual model, which incorporated two important models, was also introduced. Out of all ten hypotheses, only two were not supported that are related to factors facilitating conditions and social influence. Those two factors negatively influence the HEI learners' continuance use intention. Meanwhile, the core factors for satisfaction, which are perceived usefulness and confirmation, were found to be significant. Lastly, satisfaction was proven to mediate the positive path between perceived usefulness and the continuance intention of using the gamified m-learning application.
Recommendations for Practitioners	This study offers insights into strategies that the HEIs' management should perform in securing continuance usage of the 'in-house' developed m-learning products. One of the strategies could be organising technology workshops that

will prepare their educators in implementing the institutions' gamified teaching and learning tools. Another highlighted issue is regarding the need for faculties to design an effective approach to entice educators and learners towards applying new learning technologies.

Recommendations for Researchers

This study contributes to the micro-level analysis of the continuance use intention of gamification-based m-learning applications by fostering the understanding of the phenomenon at the individual level. It is recommended that other researchers extend the research model by incorporating other theories, as this study was only based on two models (i.e., ECM and UTAUT2). Additionally, a longitudinal study could be another approach that enables researchers to collect much richer data that includes a wide array of background characteristics or control variables. Another suggestion would be applying related factors that may contribute to the discovery of effective gamified m-learning application designs.

Impact on Society

The findings of the study show the importance of confirmation made by the applications' users towards usefulness and usage satisfaction. Confirmation and perceived usefulness also have an increasingly similar impact on users' satisfaction with the application and their subsequent continuance use intention. It is also revealed that easy-to-use products are commonly expected nowadays, as users might be reluctant to spend much time on them. On the other hand, for a specific gamification-based product, it is also expected by the users for it to be capable of giving an 'enjoyable' experience, hence motivating continuance usage. As a result, an effective gamified m-learning application or product will be able to be used by Malaysian HEI learners if the developers and stakeholders develop and evaluate the usage of their products with the consideration of the information provided by this research.

Future Research

Future studies could include respondents from other diploma programmes, resulting in an in-depth analysis. It is needed to support the generalizability of the findings in this study by considering larger populations from all different programmes. In addition, similar research can be done based on different circumstances; for instance, use of the gamified m-learning application during the in-campus physical classes instead of virtual classes (online), which might influence the users' perception in terms of the social influence and facilitating condition.

Keywords

gamified m-learning, gamification, expected confirmation model, extended unified theory of acceptance and use of technology, continuance use intention

INTRODUCTION

In accordance with the current demands of the twenty-first century, Higher Education Institutions (HEIs) have faced a vast transformation in teaching and learning systems and approaches. It is now a trend for m-learning applications to include gamification concepts that incorporate play and fun elements (Ishaq et al., 2021), in which the product will become a 'gamification-based' m-learning application or also mentioned as a 'gamified' m-learning application. Gamification refers to a game-like experience provided to users by applying gamification elements or mechanisms (Koivisto & Hamari, 2019). Among the gamified m-learning applications that have been used in the teaching and learning of Malaysian HEIs are e-quiz (Ismail et al., 2019), Mobile-Assisted Language Learning (MALL) (Ishaq et al., 2021), course learning (Ramle et al., 2019), Learning Management System (LMS) mobile versions such as the Moodle application (Annamalai et al., 2021), and the Edmodo application (Suka & Hamid, 2020). Using these gamified m-learning applications has increased learners' intrinsic and extrinsic motivation in using the learning tool, which eventually fostered and reinforced their learning (Benben & Bug-os, 2022; Lin et al., 2018). Specifically, the usage of those applications in Malaysian HEIs has helped the learners significantly in terms of knowledge reinforcement and retention (Lin et al., 2018; Mohamad, et al., 2020). It also promotes the 'learning on-the-go' concept, where learners have the luxury of flexibility in accessing their courses' content from their mobile devices anytime and anywhere (Lozanova, 2022).

Acquiring approval or acceptance of the new technology is much easier than retaining the HEI learners' interest in continuance use (Tam et al., 2020). The low technology usage rates among the learners affected the receptiveness of education stakeholders in investing or maintaining educational applications (Ahmad, 2020). In other words, lack of sustained usage of an application leads to difficulties for the developers to solicit users' responses to eventually improve the technology (Chiu et al., 2020), as well as gaining financial benefits if there are any, such as revenue that comes from various sources (e.g., advertisements, 'in-app' purchases, subscriptions, sponsorship, etc.) (Higgins, 2016). From the learners' outlook, lacking continued usage of m-learning applications may negatively affect their academic-related tasks and performance. This notion was based on Cho (2016), who found that users' discontinuance of a fitness and health application had caused negative impacts on the users' health. Therefore, it is necessary for HEIs to be aware of the applications' design that suits their users' expectations even at the start of the development phase.

In terms of the trend of research related to digital learning, most studies have concentrated on recognising the effect on learners' performance, engagement, and motivation (e.g., Zainuddin et al., 2020) as well as the acceptance of the product (e.g., Lestari & Nugraha, 2021; Md Yunus et al., 2021). Meanwhile, studies related to 'continuance use intention' on product use of e-learning (e.g., Al Amin et al., 2022), Massive Open Online Courses (MOOC) (e.g., Shanshan & Wenfei, 2022), Learning Management Systems (LMS) (e.g., Ashrafi et al., 2022; Widjaja & Widjaja, 2022) and m-learning application (e.g., Khlaif et al., 2022; Tam et al., 2020) were already done; however, studies on continuance use intention mainly on a gamified m-learning application is scarce (Roslan et al., 2021a; Wirani et al., 2022), making this a critical literature gap.

The current work proposes an extended version of the Expectation Confirmation Model (ECM) by Bhattacherjee (2001), a post-acceptance model that integrates elements of the Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) by Venkatesh et al. (2012), a pre-acceptance model, to examine the factors that influence the users' continuance intention to use a gamified m-learning application. Firstly, this study identifies relevant determinants from the UTAUT2 which represents the explanatory elements and combines them with the exploratory elements from the ECM model (Bhattacherjee, 2001). Secondly, by investigating the determinants of learners' continuance intention to use the gamified m-learning application, a contribution can be made to the broader body of knowledge related to this topic. This is critical because the majority of earlier educational information technology (IT) studies mainly focused on the initial acceptance, while this study focuses on investigating the post-acceptance phase of gamified m-learning applications' usage.

THEORETICAL BACKGROUND

This section presents the theoretical basis of this study. The Expected-Confirmation Model (ECM) proposed by Bhattacherjee (2001) and the Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) by Venkatesh et al. (2012) are explained together with the relevant literature for a broader understanding of the role of technology, IT usage, and user intention. Lastly, the incorporated model of ECM and UTAUT2 proposed by this research are also discussed leading to the formulation of ten hypotheses.

EXPECTED CONFIRMATION MODEL (ECM)

Post-acceptance behaviour study using the Expected Confirmation Model (ECM) has been a popular choice (Tam et al., 2020; Yang et al., 2022). The robustness of the ECM is due to the foundation theories derived, which were from the Expectation Confirmation Theory (ECT) and Technology Acceptance Model (TAM). Bhattacherjee (2001) adapted the ECT and TAM to produce ECM in Figure 1, which supports three variables to predict and explain the individuals' continuous intention of technology usage. The variables are satisfaction, confirmation of expectations, and perceived usefulness. In the confirmation stage, users evaluate whether their initial expectations have been adequately met after accepting and using the technology. The level of their confirmation affects their satisfaction with the technology and their perception of its usefulness. As a result, perceived usefulness and satisfaction jointly determine their intention to continue using the technology. Continuance use of intention as a construct is being used to measure whether a user (learner) is accepting a new technology or approach beyond the initial satisfaction as well as an indicator of future behaviours.

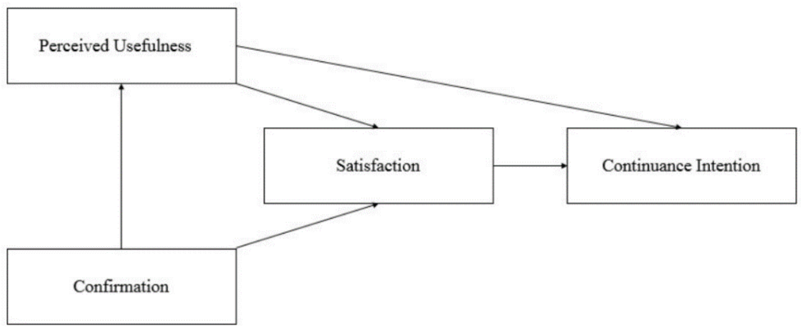


Figure 1. Expected Confirmation Model (ECM) by Bhattacherjee (2001)

A few recent m-learning application studies that also incorporated ECM in their proposed frameworks are by Tam et al. (2020), Alhumaid (2021), and Alzaidi and Shehawy (2022). First, Tam et al. (2020) applied ECM with the addition of UTAUT2 factors in their continuance use intention study of mobile applications among university students in Lisbon. They discovered that the students were directly and meaningfully influenced by their satisfaction and performance expectancy (i.e., perceived usefulness) of mobile application usage. Later, Alhumaid (2021) proposed an integrated model using theoretical models such as the Theory of Planned Behavior (TPB), the TAM, and the ECM and discovered that attitude was the best predictor for using the m-learning system. In recent research, Alzaidi and Shehawy (2022) proposed a conceptual framework for the continued intentions of learners to use m-learning during the COVID-19 outbreak expanding the UTAUT and the ECM under different cultural contexts. These previous studies proved the validity of ECM modification by incorporating several other explanatory constructs derived from the pre-acceptance model, for example, variables from the UTAUT or UTAUT2.

EXTENDED UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT2)

In the pre-acceptance or pre-adoption domain, the Unified Theory of Acceptance Use of Technology (UTAUT), inspired by Venkatesh et al. (2003) suggested that the acceptance of technology is primarily driven by performance expectancy or perceived usefulness, effort expectancy, also known as perceived ease of use, social influence, and facilitating conditions. Additionally, these relationships are moderated by gender, age, experience, and voluntariness of use. The Extended Unified Theory of Acceptance Use of Technology (UTAUT2) by Venkatesh et al. (2012) in Figure 2, which is an extended version of UTAUT, was formulated in order to better adapt it to the consumer use framework, and it introduces three new variables, which are hedonic motivation, price value, and habit. While hedonic motivation and price value are solely related to intentions to use, habit is related to both intentions to use and actual usage. Moreover, UTAUT2 includes a new relationship between the facilitating conditions and the intention to use. Since consumption in the consumer environment is always voluntary, UTAUT2 eliminates voluntariness of use as a moderating variable. Instead, it introduces experience as a moderator in the relationship between intentions to use and usage.

Based on the previous finding, most of the studies that implemented the UTAUT model as the theoretical framework used only part of the variables, while moderators are excluded in most of the studies due to low applicability use (Al-Mamary, 2022; Li & Zhao, 2021; Marchewka et al., 2007). For instance, Marchewka et al. (2007) showed that the moderating role of gender and age are irrelevant in online learning systems for college students. Meanwhile, because the samples in Li and Zhao's (2021) study were all college students of similar age and background and had high consistency of samples, the four moderators in the UTAUT model were not applied. On the other hand, Al-Mamary (2022) did not bother to include any moderators as those were not the aim of his research interest.

In recent years, both the UTAUT and UTAUT2 have been applied to examine the acceptance of mobile-based technologies and other technology contexts (Castanha et al., 2021; N. Singh et al., 2020; Tamilmani et al., 2021). UTAUT2 was also used to investigate technology continuance use intention. For example, research by Tam et al. (2020) on mobile application among learners in Lisbon, Portugal, and the latest by Osei et al. (2022) which focused on the e-learning adoption during the COVID-19 pandemic era among the learners of tertiary education in Ghana. In conclusion, the constructs from the pre-acceptance model, UTAUT2, are a valid addition to a post-acceptance model to uncover technology continuance use intention contributors.

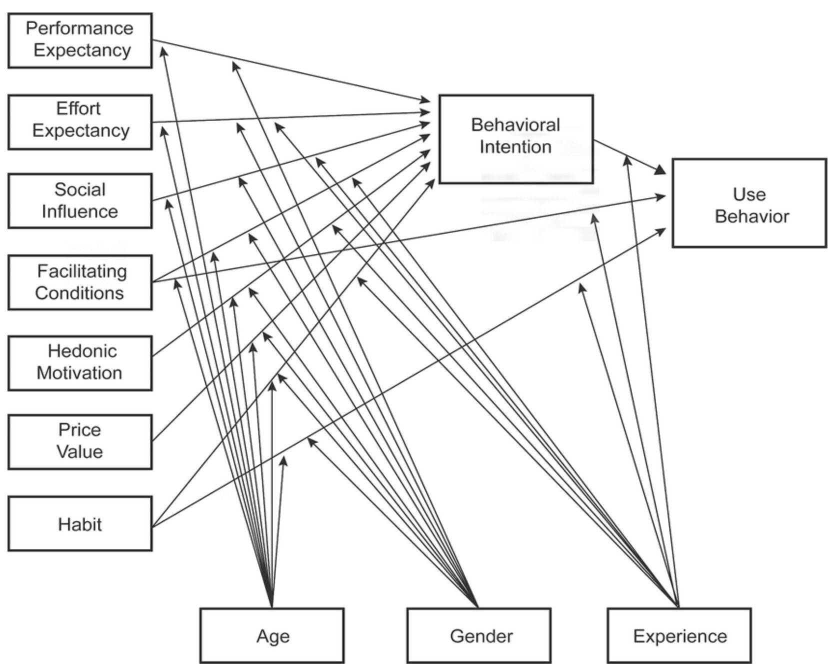


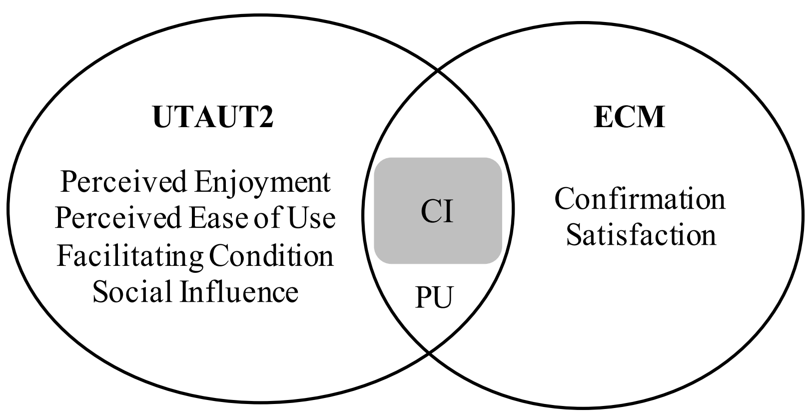
Figure 2. Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) by Venkatesh et al. (2012)

INCORPORATED MODEL OF ECM AND UTAUT2

Motivated by the fact that there is a lack of research on learners' continuance use intention, specifically in a 'gamification-based' or 'gamified' m-learning application, this study applied a robust post-usage model (i.e., ECM) as the base model. In order to reveal more information or, in other words, increase the explanatory power of this continuance use of intention research, more variables were incorporated into Bhattacherjee's (2001) ECM model. The variables were derived from the technology pre-acceptance or pre-adoption model, namely the UTAUT2 from Venkatesh et al. (2012). Behavioural intention and use behaviour are typically associated with the pre-acceptance stage of technology (Venkatesh et al., 2003), whereas continuance use intention encompasses the post-acceptance stage of a technology (Bhattacherjee, 2001). Of the nine constructs from UTAUT2, only five are related to the technological product used in this study, which are: (i) facilitating condition (FC), (ii) social influence (SI), (iii) effort expectancy/perceived ease of use (PEOU), (iv) hedonic motivation/perceived enjoyment (PENJ), and (v) performance expectancy/perceived usefulness (PU).

For factor price value (PV), it can be included in the proposed model if this research focuses on the perspective of the educator (i.e., educators as the population); however, this research focused on the student as the type of user, or in other words, student module. Therefore, the price value factor is not applicable due to payment or purchase not being imposed on students' accounts. In the case of another two unselected UTAUT2 variables (i.e., behaviour intention, use behaviour), those variables indicate the pre-adoption research, which is an assessment related to technology pre-adoption or pre-acceptance, while this research focuses on the post-adoption or post-acceptance phase (i.e., continuance use intention). On the other hand, the habit (H) factor is not included due to two reasons: (i) sufficient time has not elapsed for users to trigger habit at the early stage of technology adoption, and (ii) habit usually occurs more naturally under voluntary settings, while experience on the usage of the product is usually acquired under mandatory settings. Similarly, Tamilmani et al. (2018) also mentioned these same reasons for not including the habit (H) factor in their study as well.

This study was conducted during the COVID-19 outbreak which witnessed the instant shift to virtual or online learning tools leading to increased levels of stress as a result of escalated on-screen time (Mheidly et al., 2020). Moreover, more independent learning hours had to be spent to complete the learners' academic tasks which left the learners with limited resting hours (Azlan et al., 2020). Hence, the learners were most unlikely to develop a habit towards the use of the technological product (i.e., Kingdom Quizzes) as it requires a lot of time and attention, and the usage of the product is usually for the mandatory situation. Meanwhile, ECM contains four constructs (i.e., perceived usefulness, confirmation, satisfaction, continuance use intention), and all the constructs are related to the technological product used in this study. Considering that this research involves the use of an online learning system (i.e., m-learning), all the participants are first-year diploma students (i.e., 19 years of age), and are in their second semester which means that all of them had experienced using various educational systems in that institution, hence the moderators associated with the UTAUT2 were deemed irrelevant to be included in this study. The theoretical framework is shown in Figure 3.



Note. PU (Perceived Usefulness); CI (Continuance Use Intention)

Figure 3. The theoretical framework adopted from ECM and UTAUT2

Hypotheses

Ten hypotheses are presented based on the proposed model in Figure 4. The first and second hypotheses are related to the confirmation of expectations which implies the degree of the perceived congruence between the expectations of the IT product/service and its actual performance (Bhattacherjee, 2001; Chiu et al., 2020). Users who validate their prior assumptions regarding a particular IT solution might immediately see its advantages. Meanwhile, users' confirmation of expectations managed to obtain the expected benefits through their IT usage, thereby leading to a positive effect of perceived usefulness and satisfaction with the IT product (Han & Conti, 2020; S. Singh, 2020; F. Zhou et al., 2021). Therefore, this study will view confirmation as the HEI learners' perception of the similarity between their expectation of the usage of gamified m-learning application with the actual operation. In other words, the actual learners' experience while using the application, has to confirm the learners' initial expectations. Therefore, the following hypotheses are posed:

> **H1a: Confirmation (C) has a positive effect on satisfaction (S) in using gamified m-learning applications.**
>
> **H1b: Confirmation (C) has a positive effect on the perceived usefulness (PU) of gamified m-learning applications.**

The third and fourth hypotheses are related to the construct of perceived usefulness, reflecting that a person believes using a specific system would boost job performance (Davis, 1989). Perceived usefulness is an essential factor that is also referred to as performance expectancy (Tam et al., 2020). It is commonly explored to verify the products' level of usability, leading to satisfaction, and is widely considered in continuance usage intention studies (e.g., Kim & Nam, 2019; S. Singh, 2020). Therefore, in this study, the users will be satisfied upon using the gamified m-learning application if their expectation of the application's ability to perform their academic tasks faster with mobility's advantage is fulfilled. Hence, the basis for hypothesis H2a.

On the other hand, Premkumar and Bhattacherjee (2008) confirmed perceived usefulness as the predictor of intention in TAM and a dependable predictor of continuance use intention. The application in this study is expected to be the automated version of the traditional (paper-based) process and able to be used on mobile devices. Therefore, hypothesis H2b was formulated based on the users' belief that using the gamified m-learning application is very useful to them, especially when they are 'on the go' regardless of their physical location, which triggers their interest in continuous use of the product. Drawing on the above cases, it is suggested that:

> **H2a: Perceived usefulness (PU) has a positive effect on satisfaction (S) in using the gamified m-learning application.**
>
> **H2b: Perceived usefulness (PU) has a positive effect on gamified m-learning application continuance use intention.**

The next hypothesis is related to the construct of perceived enjoyment. Perceived enjoyment is considered as a form of intrinsic motivation that can lead to emotional arousal and stipulates the extent to which fun can be acquired from using IT or IS (Chao, 2019). Sharifi Fard et al. (2019) and Akdim et al. (2022) highlighted that perceived enjoyment is also referred to as hedonic motivation. Numerous studies have proved that enjoyment is a particularly powerful predictor of usage decisions for technologies, for example, the MOOC (Tao et al., 2022), online education platforms (L. Zhou et al., 2022), virtual reality (Zhang et al., 2022), augmented reality (Alsharhan et al., 2022), and m-learning application (Al-Bashayreh et al., 2022).

The fifth hypothesis is based on reliable evidence confirming the link between perceived enjoyment, which is the hedonic aspect of technology, with continuance use intention (Akdim et al., 2022). As the technological product for this research consists of all three MDA gamification elements (i.e., mechanic, dynamic, aesthetic) and offers an interconnected strategy game, it is assumed that a learners' perceptions about the hedonic aspect of a gamified m-learning application will have a positive impact on their willingness to continuance using the product. Therefore, the following hypothesis is posed:

> **H3: Perceived enjoyment (PENJ) has a positive effect on gamified m-learning application continuance use intention.**

The construct perceived ease of use, referred to as effort expectancy, is the degree of belief that using a specific technology will be free of effort (Davis, 1989). According to Tam et al. (2020), when users strongly believe that a mobile application is indeed practical, therefore they may also believe that the application is difficult to use, which contributed to the idea that the benefits of using it are offset by the effort to use the application. An assumption is that the simple and user-friendly functionalities of the gamified m-learning application will likely make the learner perceives it as easy to use and useful during the execution. If the application is relatively helpful and easy to use, learners will be more willing to learn about the features and finally have the intention to continue use (L. Y. Wang et al., 2019). Hence, the next hypothesis is posed:

> **H4: Perceived ease of use (PEOU) has a positive effect on gamified m-learning application continuance use intention.**

According to Venkatesh et al. (2003, 2012), facilitating conditions are the degree to which the individual perceives the existence of resources and support to use a specific technology whenever necessary. Previously, Nysveen and Pedersen (2016) stated that a consumer who has access to a favourable set of facilitating conditions is more likely to have a greater intention to use technology. Furthermore, a recent study by Kamarozaman and Razak (2021) related to e-campus continuance use intention found that facilitating condition plays an essential contributor. Therefore, the formation of the seventh hypothesis is based on the more facilitation conditions associated with using the gamified m-learning application, the more a user will continue to use them. Therefore, the following hypothesis is posed:

> **H5: Facilitating condition (FC) has a positive effect on gamified m-learning application continuance use intention.**

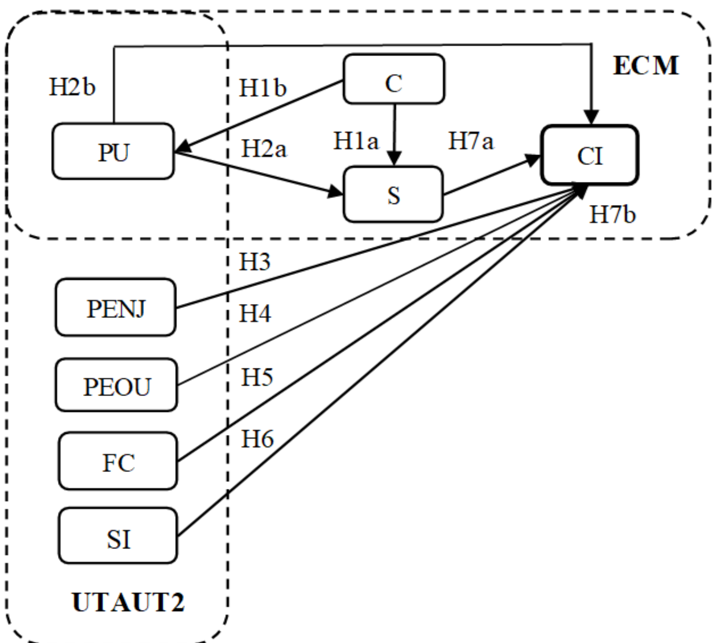
For social influence, Venkatesh et al. (2003) described social influence as the degree to which a person perceives that important people around them believe that everyone should use the new. Generally, the perception of others influences the intentions to use a particular technology. This is an important factor in determining the acceptance and continuance use of technology. Likewise, Wu and Chen (2017) stated that when an individual observes that others use the technological application and perceive the benefits of its implementation, that individual will become more willing to use the application, which can increase both present and future usage of the technology. Vanduhe et al. (2020) established that when a user observes that his/her peers are using gamification and acknowledged the benefits of its use, that individual will be inspired to implement gamification for training in the present and the future. For this study, it is expected that social influence entails the learners' perception of usefulness from others and plays a vital role in driving attitudes toward using the gamified m-learning application. Hence, the following hypothesis is posed:

> **H6: Social influence (SI) has a positive effect on gamified m-learning application continuance use intention.**

In the application context, consumer or user satisfaction is the state of satisfaction that comes from the performance that meets expectations (Phuong et al., 2020). Studies by Bagaskara et al. (2021) and Yang et al. (2022) have reported that satisfaction is significant towards the continuance usage intention. The students' expectations of the performance of learning technology are indeed interconnected with their satisfaction, and then later affect their intention to continue implementing technology blended learning (Yang et al., 2022). Meanwhile, Bagaskara et al. (2021) confirmed that due to Google Classroom's easy-to-use features, students felt satisfied with their user experience, hence having the intention to continue using the LMS. Therefore, the formulation of hypothesis H7a in this study revolves around the users feeling content with the gamified m-learning applications' services and pleasing experience, which is an important aspect in securing their intention to use the product again.

In another case, Yang et al. (2022) also found that satisfaction mediates the impact of beginners' perceived usefulness towards continuance use intention of blended learning in HEI. Previously, Islam and Azad (2015) confirmed satisfaction as a mediating factor between the usefulness and continuance use of an e-learning system. It is said that both the students and educators expressed positive views on the usefulness of the Learning Management System (LMS), which triggered their satisfaction to continually use the LMS. Following that, Joo et al.'s (2017) study also found that satisfaction played a mediating role in linking perceived usefulness and continuance use intention towards digital textbooks. Therefore, in this study, satisfaction is also predicted to influence the mediating effect between perceived usefulness and continuance use intention due to the expectation that users need to be satisfied with the impact of the gamified m-learning usage and the ability to complete their academic tasks. Thus, the formation of hypothesis H7b is as follows:

> **H7a: Satisfaction (S) has a positive effect on gamified m-learning application continuance use intention.**
>
> **H7b: Satisfaction (S) positively mediate the relationship between perceived usefulness (PU) and continuance use intention of the gamified m-learning application.**



Note. PU (Perceived Usefulness); PENJ (Perceived Enjoyment); FC (Facilitating Condition); PEOU (Perceived Ease of Use); SI (Social Influence); C (Confirmation); S (Satisfaction); CI (Continuance Use Intention)

Figure 4. Research model

In conclusion, the incorporation of UTAUT2 and ECM allows capturing of data relating to two use perceptions, pre- and post-usage perceptions of the gamified m-learning application. However, the original continuance usage intention model (i.e., ECM) cannot fully explain the post-acceptance influencing factors of the application without the introduction of certain modifications, such as embedding constructs that also represent the expected behaviours of learners.

METHOD

RESEARCH CONTEXT AND PARTICIPANTS

This study was conducted in one of Malaysia's public universities, specifically at the Centre for Diploma Studies (CeDS), Universiti Tun Hussein Onn Malaysia (UTHM). Diploma programmes are considered post-secondary education or tertiary education, generally receiving enrolment from students aged 18 years old. In CeDS, UTHM, the diploma study is conducted for two and a half years (i.e., five semesters), and the last semester is dedicated to industrial training, meaning there would be no teaching and learning sessions. The gamified m-learning application involved in this study is an android-based e-quiz mobile application called Kingdom Quizzes and developed by UTHM. The Kingdom Quizzes application offers more than just a quiz module, it also offers an interconnected game module (i.e., tower defence strategy game). The types of activities that the learners can perform are: (i) executing quizzes, (ii) revision, and (iii) gameplay. Furthermore, the gamification items employed by Kingdom Quizzes are: (i) points, (ii) leaderboard, (iii) performance list, (iv) virtual gifts, (v) level and challenges, and lastly, (vi) avatar/personalised image. Figure 5 displays the activities in Kingdom Quizzes done by the learners.

Figure 5. Activities done using the Kingdom Quizzes application

This study employed a correlational cross-sectional research design using an online survey. The participants of the final survey are the first-year students of diploma programmes: Civil Engineering, Animation, and Information Technology, who are 'active' Kingdom Quizzes users. The 'active' status refers to students who had completed more than 50% of the total published quizzes during that semester. This restriction is enforced based on the perception that inactive users may not be able to give reliable answers to the questions posed in the survey due to their low involvement with the product. The usage of Kingdom Quizzes, consisting of all the aforementioned activities, was done for eight weeks in a semester, and the number of quizzes published for each course is at least three sets. Details of the procedure are stated in Table 1.

Table 1. Research procedure performed in one semester (14 weeks)

Week	Activity/Task
1–3 (3 weeks)	• Discussion with participating educators • Finalized quiz content, schedule, list of students • Quiz setup and testing
4–5 (2 weeks)	• Briefing on the Kingdom Quizzes usage to the students • Application download, installation, and testing
6–13 (8 weeks)	• Quiz publishing by educator • Quiz execution, quiz revision, game playing (i.e., interconnected strategy game) by students • Quiz marks and grade compilation by educator
14 (Survey week)	<u>Before the survey session</u> • Preparation of 'active' and 'inactive' students' listing by educator <u>During the survey session</u> • At the start of the session, students' attendance was collected and checked to ensure the participants are the targeted participants (i.e., 'inactive' students are dismissed) • Briefing on the Kingdom Quizzes application and survey that will be conducted • A Google Form link is given in the chat section. Respondents are reminded to turn on their web camera while answering the survey and encouraged to ask any questions regarding the items posed in the survey • After the survey completion, respondent will acknowledge the educator on their exit so that the number of completed responses can be cross-validated or cross-checked

At the end of the semester, the Google Form link containing the research survey was distributed to the 'active' students (i.e., students who had completed more than 50% of overall published quizzes throughout the semester) in a Google Meet session (Figure 6). Due to conducting an online survey, it is important that the survey link is given to the eligible person (i.e., UTHM Diploma students who used the Kingdom Quizzes application to perform authorized quizzes, throughout the whole semester). This is to prevent any form of abuse (e.g., unauthorized respondents or unknown responses, multiple insertions) towards the data collection done through an open link (i.e., Google form link). Hence, it is important for educators to identify all the students that are in the Google Meet session at the time.

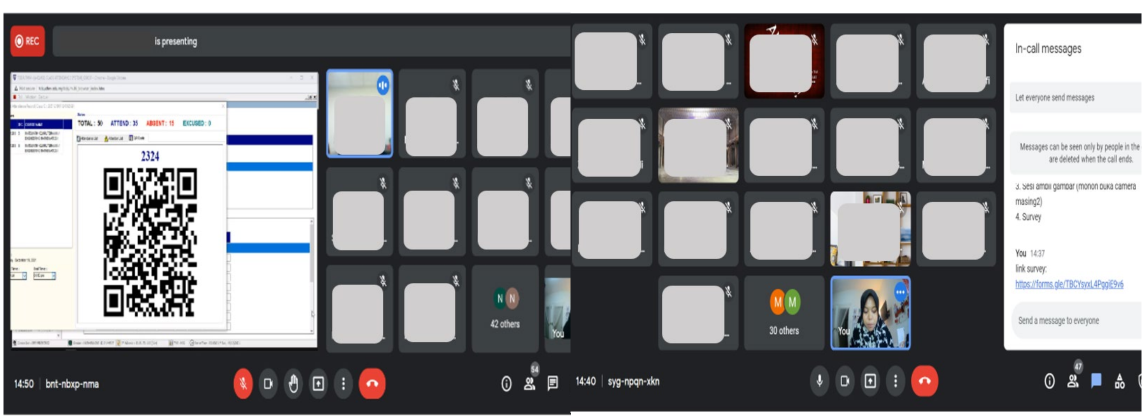


Figure 6. Google Meet survey session

A total of 317 questionnaires were collected during the survey session. Subsequently, 48 responses were excluded due to the existence of extreme cases identified from Mahalanobis's multivariate outlier test (Leys et al., 2018). In conclusion, 269 valid responses remained for further analysis. Overall, the responses consisted of 129 (48%) female and 140 (52%) male respondents, and the programme distributions are: 103 out of 240 students of civil engineering (38.3%), 44 out of 100 students of animation (16.4%) and 122 out of 220 students of IT (45.3%).

MEASURES

The instrument used in this research is based on reliable existing instruments that were adapted and modified to fit the aim and context of this study. Table 2 presents the final items with the source of the instrument. All items were measured using the Likert scale of 5 – points ranging from strongly disagreed (1), disagreed (2), somewhat agreed (3), agreed (4), to strongly agreed (5). Prior to data collection, a pre-test was carried out in which the survey items were evaluated by five experts in the field of educational technology. Subsequently, a pilot test with 60 first-year students from the previous cohort of student enrollment was performed to ascertain the reliability of items at the preliminary stage. The Cronbach's Alpha (α) values of each construct based on the result of the pilot study are also presented in Table 2. Based on Hair et al. (2014), the reliability score of .70 or higher is the ideal threshold for obtaining suitable reliability of an instrument and the Cronbach's Alpha (α) values for each construct are displayed as .70 and above. Meanwhile, the average value of Cronbach's Alpha (α) for the whole instrument is .770, which shows that the instrument is acceptable and reliable for this research. Hence, the instrument is declared fit to be used in the actual study. The full items or instrument is presented in the Appendix.

Table 2. Details on the instrument including reliability test (Cronbach's Alpha) based on the pilot study

Construct	Number of Items	Source	Cronbach's Alpha (α)
Perceived Usefulness (PU)	5	Bhattacherjee (2001); Venkatesh et al. (2012)	.818
Perceived Ease of Use (PEOU)	5	Venkatesh et al. (2012)	.760
Social Influence (SI)	5	Venkatesh et al. (2012)	.701
Facilitating Conditions (FC)	5	Venkatesh et al. (2012)	.713
Perceived Enjoyment (PENJ)	4	Venkatesh et al. (2012)	.707
Satisfaction (S)	6	Bhattacherjee (2001)	.831
Confirmation (C)	6	Bhattacherjee (2001)	.855
Continuance Use Intention (CI)	5	Bhattacherjee (2001)	.776
Total	41	Average (α)	.770

DATA ANALYSIS

Prior to evaluating the model, the 269 final data were examined for multivariate normality using a multivariate coefficient. The multivariate coefficient is one of the techniques that is used to assess multivariate normality, as demonstrated in Mardia (1970). Based on Mardia's coefficient procedure, the kurtosis coefficient ($\beta = 103$) was above the threshold score of 20, indicating data being non-normally distributed (Byrne, 2013; Kline, 2015). For this reason, partial least square-structural equation modeling (PLS-SEM) is more appropriate to be applied through the use of a non-parametric inferential technique (i.e., bootstrapping) (Sarstedt et al., 2021). The final data, which is 269, complied with the minimum sample size that is proposed in PLS-SEM (i.e., $n > 160$) (Kock & Hadaya, 2018).

Before proceeding to the first data analysis procedure to verify the measurement model, Common Method Bias (CMB) is tested. It is said that the CMB can overemphasise the strength of the relationships among the variables in the model due to all the responses were gathered from a similar source.

The CMB is assessed through two types of approaches: (i) Harman's Single Factor (HSF) (Podsakoff, 2003), and (ii) full collinearity assessment (Kock & Lynn, 2012). According to the recommendation of Podsakoff (2003), the HSF results illustrated that the largest variance explained by an individual factor was 30.23% (< 50%). Furthermore, the assessment of full collinearity produced a variance inflation factor (VIF) below 3.30 (Kock & Lynn, 2012), as shown in Table 2. This concludes that this study has no issue related to CMB.

Starting with the first data analysis step, which is assessing the measurement model with the purpose of checking the reliability and validity of the construct, this involves (i) an internal reliability test, (ii) a convergent validity test, and (iii) a discriminant validity test (Hair et al., 2011), which will reveal how well the observed variables represented the latent variables. The internal reliability is acceptable when the composite reliability value is .70 or higher (Bagozzi & Yi, 1988). Meanwhile, for convergent validity, the threshold value of the average variance extracted (AVE) is above .50 (Nunnally & Bernstein, 1994). Lastly, discriminant validity is being checked using the Heterotrait-Monotrait ratio of correlations (HTMT) due to its superior performance based on Ghasemy et al. (2020). The threshold value below .90 (Gold et al., 2001) is selected in this study to identify the discriminant validity of the variables involved.

Next, the validation of the structural model was conducted to find the relationships among the variables set in this study. All the constructs in this research were measured using reflective measurement models as each set of the observed variables (indicators) can be classified as manifestations of the underlying constructs. The evaluation was done using five steps: (i) the lateral collinearity (VIF) (Becker et al., 2015), (ii) the path coefficients, (iii) the coefficient of determination (R^2) (Hair et al., 2019), (iv) the effect size (f^2) (Cohen, 1988), and (v) the predictive accuracy (Q^2) (Geisser, 1975; Shmueli et al., 2016, 2019; Stone, 1974).

RESULTS

This section provides a report on the measurement model and structural model analyses based on the finalized data set and preliminary data examination performed in the previous section. In the end, analysis based on the original ECM was also conducted as a comparison measure in order to prove the relevance of the proposed research model.

VERIFICATION OF THE MEASUREMENT MODEL

For the measurement model, the convergent validity can be assessed based on (i) outer loading and (ii) average variance extracted (AVE). Outer loading value that is high means that the indicators most likely belong to the construct. As recommended by Hair et al. (2021), the outer loadings that should be achieved are .708 and above to indicate that the construct is capable in explaining at least 50% of the indicator's variance. In contrast, the outer loadings with a value less than .40 should be discarded (Bagozzi et al., 1991; Hair et al., 2021). However, the items with outer loadings more than .40 can be accepted if the construct has achieved .50 and above for the AVE score (Hulland, 1999; Ramayah et al., 2016).

In addition, seven items (i.e., SIN1 = .357; FCO1R = .323; FCI2 = .514; CU1R = .264; PEOUE1 = .697; SIE2R = .558; SS1R = .561) were removed due to low loading, which is less than .708 (Hair et al., 2019); however, one of the satisfactions' items (SD1R= .521), one of the facilitating conditions' items (FCO2= .634) and two of the continuance use intentions' items (CIU4R = .510, CIR2 = .697) were retained as the AVE of each construct is already greater than .50. The values of AVE ranged from .523 to .647 and the composite reliabilities were greater than .70, indicating sufficient internal reliability and convergent validity. The internal and convergent validity results are in Table 3. The next assessment is associated with discriminant validity using the Heterotrait-Monotrait ratio of correlations (HTMT), displayed in Table 4. The HTMT values were below the conservative threshold limit of .90 (Gold et al., 2001), thereby establishing discriminant validity.

Table 3. Full collinearity, internal reliability, and convergent validity results

Latent Variable	Item	Loading	Random Dummy Variable (VIF)	Cronbach's Alpha (α)	Composite Reliability (> .7)	AVE (> .5)
Perceived Usefulness (PU)	PUP1 PUT2 PUT3 PUU2 PUU3	0.801 0.740 0.808 0.794 0.824	1.170	.854	.895	.631
Perceived Ease of Use (PEOU)	PEOUI2 PEOUI3 PEOUI4 PEOUI5	0.786 0.727 0.763 0.727	1.149	.743	.838	.564
Social Influence (SI)	SIE1 SIO1 SIO2	0.729 0.885 0.837	2.158	.755	.859	.671
Facilitating Condi-tions (FC)	FCK1 FCO2 FCT1	0.777 0.634 0.750	1.336	.543	.766	.523
Perceived Enjoyment (PENJ)	PENJE1R PENJE2R PENJF1R PENJI1	0.727 0.728 0.814 0.700	1.474	.750	.831	.553
Satisfaction (S)	SD1R SD2 SI1 SS2 SS3	0.521 0.752 0.828 0.783 0.797	1.060	.795	.859	.554
Confirmation (C)	CP1 CP3 CS1 CS1a CS2	0.836 0.808 0.776 0.791 0.808	2.731	.863	.901	.647
Continuance Use In-tention (CI)	CIR1 CIR1a CIR2 CIU1 CIU4R	0.861 0.861 0.697 0.826 0.510	2.632	.809	.871	.582

Table 4. HTMT results for discriminant validity assessment

	1	2	3	4	5	6	7	8
1. Confirmation								
2. Continuance Use Intention	0.896							
3. Facilitating Condition	0.883	0.744						
4. Perceived Ease of Use	0.888	0.845	0.883					
5. Perceived Enjoyment	0.529	0.716	0.447	0.608				
6. Perceived Usefulness	0.898	0.856	0.888	0.885	0.538			
7. Satisfaction	0.863	0.889	0.769	0.802	0.751	0.797		
8. Social Influence	0.814	0.761	0.892	0.859	0.568	0.833	0.843	

Note. HTMT < 0.90

Verification of the Structural Model

To evaluate the structural model, the study begins with examining the lateral collinearity (VIF) between the latent variables. Table 5 shows that VIF values were between 1 and 2.789, which is below the cut-off score of 3 (Becker et al., 2015), indicating the problem of multicollinearity issue is not a concern. Next, the hypotheses in the structural model were tested by using a bootstrap re-sample technique with an iteration of 5,000 sub-sample. Table 5 presents the corresponding results, while Figure 7 illustrates the path coefficients calculated from t-statistics and R^2 of the proposed model.

Table 5. Hypotheses testing and structural model assessment results

	β	Indirect Effect	Confidence Interval	*t*-value	*p*-value	Inner VIF	R^2	f^2	Q^2	Result
H1a: C -> S	.524		(.428, .630)	8.484**	.000	2.523	.577	.257	.305	S
H1b: C -> PU	.777		(.735, .821)	29.652**	.000	1.000	.604	1.523	.368	S
H2a: PU -> S	.277		(.162, .386)	4.092**	.000	2.523		.072		S
H2b: PU -> CI	.314		(.189, .416)	4.587**	.000	2.789	.660	.104	.372	S
H3: PENJ -> CI	.182		(.080, .278)	3.032**	.001	1.598		.061		S
H4: PEOU -> CI	.149		(.056, .243)	2.607*	.005	2.458		.026		S
H5: FC -> CI	- .014		(-.095, .078)	.264	.396	1.775		.000		NS
H6: SI -> CI	.026		(-.074, .133)	.421	.337	2.343		.001		NS
H7a: S -> CI	.298		(.191, .420)	4.357**	.000	2.524		.104		S
H7b: PU -> S -> CI		.083	(.036, .142)	3.040*	.002					S

*Note. * p < .01, **p ≤ .001; S (Supported); NS (Not supported); PU (Perceived Usefulness); PENJ (Perceived Enjoyment); FC (Facilitating Condition); PEOU (Perceived Ease of Use); SI (Social Influence); C (Confirmation); S (Satisfaction); CI (Continuance Use Intention); VIF (Variance Inflation Factor)*

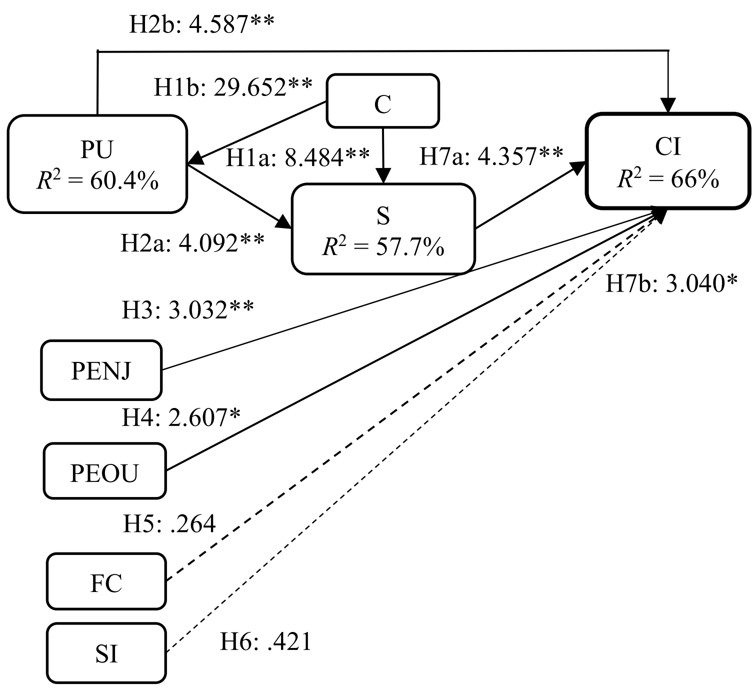
Confirmation (H1a: β = .524, t = 8.484, p = .000) and perceived usefulness (H2a: β = .277, t = 4.092, p = .000) have direct positive effect on satisfaction. Meanwhile, confirmation positively influenced perceived usefulness (H1b: β = .777, t = 29.652, p = .000). The result proved that most of the relationships have a positive effect on continuance use intention, which involved perceived usefulness (H2b: β = .314, t = 4.587, p = .000), perceived enjoyment (H3: β = .182, t = 3.032, p = .001), perceived ease of use (H4: β = .149, t = 2.607, p = .005) and satisfaction (H7a: β = .298, t = 4.357, p = .000). However, two relationships which are the facilitating conditions with continuance use intention (H5: β = -0.014, t = .421, p = .396) and social influence with continuance use intention (H6: β = .026, t = .421, p = .337) were not statistically significant. Additionally, the mediation effect using Preacher and Hayes' (2004) bootstrapping approach was applied and confirmed that satisfaction was found to mediate the relationship between perceived usefulness towards continuance use (H7b: β = .083, t = 3.040, p = .002).

The next step involved the assessment of the coefficient of determination (R^2) which represents the in-sample predictive power. According to Hair et al. (2011), the strength of R^2 values is ideally categorised as greater than .25 equals weak, greater than .50 equals moderate, and greater than .75 can be measured as substantial. The results revealed that 66% of the variance in continuance use intention is explained by satisfaction, perceived usefulness, perceived ease of use, perceived enjoyment, facilitating condition, and social influence; 60.4% of the variance in perceived usefulness is explained by confirmation; and 57.7% of the variance in satisfaction is explained by perceived usefulness and confirmation (see Table 5).

Therefore, the in-sample predictive power (R^2) of this model is considered as moderate as all the endogenous variables showed R^2 values greater than .50. In addition, when compared with the R^2 of continuance use intention from the original or base model of ECM (Bhattacherjee, 2001) using the same research sample (R^2 = .622) as displayed in Figure 8, the results proved that the proposed research model displays increment of 3.8% (R^2 = .660). Meanwhile, the other two endogenous variables remain at the same values. This proved that extending the variables in the original ECM, it added more value, meaning that it has more explanatory power on continuance use intention than the original ECM.

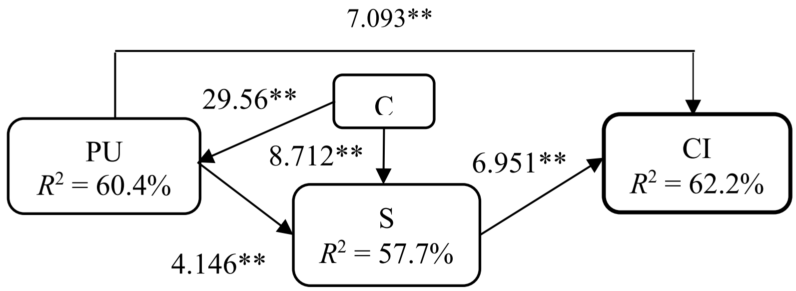
Subsequently, the effect size of the construct was assessed using Cohen's (1988) f^2, which are effect size (f^2) values above .02, .15, and .35 represent small, medium, and large effects. By looking at the f^2 values in Table 4, it can be observed that confirmation (f^2 = .257) and perceived usefulness (f^2 = .072) demonstrated moderate and small effect size in generating R^2 for satisfaction, respectively, whereas confirmation (f^2 = 1.523) portrayed a large effect size in generating R2 for perceived usefulness. On the other hand, the perceived usefulness, perceived enjoyment, perceived ease of use, and satisfaction reflect a small effect size in generating R^2 for continuance use intention. Furthermore, the facilitating condition does not exert any effect, while the social influence effect size is considered trivial with only f^2 = .001.

The last step is identifying the predictive accuracy of the structural model based on the blindfolding approach of the Geisser Stone–Geisser test criterion (Q^2). When the Q2 value exceeds the threshold of 0 for all the endogenous variables, it supports the predictive relevance of the model (Stone, 1974). However, this study enhanced the explanation of Q^2 by determining its effect using Cohen's (1988) rule of thumb where Q^2 greater than 0.02 signifies small or low, Q^2 greater than 0.15 signifies medium or moderate, while Q^2 greater than 0.35 represents large or strong predictive power (Suhan et al., 2018). As illustrated in Table 5, two endogenous variables (i.e., perceived usefulness = .368 and continuance use intention = .372) exhibited strong predictive accuracy (Q^2 value > .35), while one endogenous variable (i.e., satisfaction = .305) exhibited moderate predictive accuracy. In all, the model represents a strong predictive model for investigating the factors of gamified m-learning continuance use intention.



*Note. *p < .01; **p ≤ .001; Dashed line/arrow: hypothesis not supported; PU (Perceived Usefulness); PENJ (Perceived Enjoyment); FC (Facilitating Condition); PEOU (Perceived Ease of Use); SI (Social Influence); C (Confirmation); S (Satisfaction); CI (Continuance Use Intention)*

Figure 7. Summary of the research structural model



Note. ***p ≤ .001; PU (Perceived Usefulness); C (Confirmation); S (Satisfaction); CI (Continuance Use Intention)*

Figure 8. Original ECM structural model

DISCUSSION

KEY FINDING

Based on the results, two additional variables from the pre-acceptance model (i.e., UTAUT2), which are the perceived ease of use and perceived enjoyment, were the ones that impacted the continuance use intention of HEI learners. This finding is also consistent with the previous studies that found the significance of both variables among HEI learners towards technology continuance use intention (Kim & Nam, 2019; Roslan et al., 2021b; Ye et al., 2020). In contrast, variables facilitating condition and social influence failed to exert a positive influence, which corresponds to hypotheses H5 and H6, respectively. This is mainly because the research was conducted during the COVID-19 outbreak which heavily influenced both variables. The COVID-19 pandemic had served a different condition than usual; in Malaysia, for instance, during the outbreak which started at the end of 2019 and continued until 2021, distance learning had to take place with instant enforcement of online learning, utilising web-based and mobile-based educational tools.

In sum, out of the ten hypotheses, eight were supported (i.e., H1a, H1b, H2a, H2b, H3, H4, H7a, H7b), while the other two were rejected (i.e., H5, H6). Hypothesis H1a involves the influence of confirmation of expectation towards satisfaction in gamified m-learning usage. Indeed, the result of the finding showed that the satisfaction of Malaysian HEI learners is strongly affected by confirmation of the features and functions of the product. As the learners discover that their expectations of the product are being met, their level of satisfaction increases. This is in accordance with the findings of previous studies by Kumar et al. (2018) and Poromatikul et al. (2019). On the other hand, results related to another confirmation of expectation hypothesis (i.e., H1b) revealed that users' level of confirmation is positively associated with their perceived usefulness which is in accordance with Ouyang et al. (2017). Thus, it can be concluded that, as learners' expectations of gamified m-learning increase, their perception of the usefulness of the application may also increase. This signifies that when learners confirm the expected benefits from the gamified m-learning, they will believe it is worth using and tend to expect more from it in their future use.

The supported hypothesis H2a is related to the effect of the perceived usefulness of the gamified m-learning application usage toward the users' satisfaction. The result is in line with Ouyang et al. (2017) and Wilson et al. (2021). As the learners felt that there was an 'added value' that they could get, or when they felt that their academic performance would be improved by using the technological product (i.e., Kingdom Quizzes), then it could increase their satisfaction with the product, or even towards the HEI which produced it. Meanwhile, the finding of this research is in support of H2b, which also reflects the results of Alshurideh et al.'s (2020) and Tam et al.'s (2020) studies on continuous intention to use the mobile application in HEI. This confirms that the usefulness of an m-learning product for the purpose of completing the learners' academic task is highly expected as it is usually the users' goal in the first place.

Additionally, perceived enjoyment is also found to be one of the antecedents of continuance use intention among HEI learners on a gamified m-learning application, as it was found to have a positive influence, supporting hypothesis H3. This also agrees with the finding by Yan et al. (2022), which proved that perceived enjoyment has a significant positive influence on the student's intention to participate in an online gamified classroom. Each participation will boost their desire for further usage. Another antecedent of gamified m-learning application continuance use intention is perceived ease of use, which supported hypothesis H4 in this research. The result was also in line with Saeed Al-Maroof et al.'s (2021) study which confirmed the significant role of perceived enjoyment towards continuous intention to use technology in HEI. Meanwhile, Fathema et al. (2015) also mentioned that perceived usefulness and perceived ease of use are the most influential factors in users' continuance use intentions. However, Cai et al. (2019) have proven that perceived usefulness is more effective than perceived ease of use when one wants to deal with the use of technology.

On the contrary, hypothesis H5 was not supported in this study, which corresponds with Marandu et al.'s (2022) research related to continuance use intention for online learning among HEI learners in the post-COVID-19 pandemic. Marandu et al. (2022) revealed that the facilitating condition has a negative influence. This is because the learners had already felt that online learning could be managed on their own or already self-facilitated during the pandemic. Similarly, the negative effect of facilitating conditions in this research is also due to the learners having been used to incorporating internet usage to support daily academic tasks and applying smartphones to their daily routines. This had provided the ideal conditions for online and mobile learning usages; hence they give no importance to the issue of the facilitating conditions.

For hypothesis H6, the finding showed that social influence negatively affected the continuance use intention on gamified m-learning applications which is similar to Dramani et al. (2022), where they found that social influence also displayed insignificance towards continuance use intention of the e-learning system in the Ghana HEI during the COVID-19 pandemic. Their study predicted that the reason for its insignificance is due to social influence only influences the behavioural intention of IT users in the early stages of adoption. In the case of this research, the sudden order for virtual learning limited the institution and educators' active involvement in encouraging and influencing the learners during the usage of the Kingdom Quizzes application. It also degraded the interactions among peers, affecting Kingdom Quizzes' usage influence from their circle of friends.

Another antecedent of the continuance use intention for gamified m-learning applications that was confirmed through the finding in this study is satisfaction, which reflects hypothesis H7a. Rohan et al.'s (2021) research found that satisfaction is the most significant predictor of continuance use intention among HEI learners in Thailand and is parallel with the finding of this study. They found that achievement-related gaming elements have a positive effect on user need satisfaction and feeling of fun while using the MOOC, resulting in higher time spent in the specific related course. This situation may also have occurred during the usage of Kingdom Quizzes, the gamification-based m-learning application used in this research. Evidently, the predicted variable satisfaction proved to mediate the link between perceived usefulness and continuance use intention, hence hypothesis H7b is supported. This verifies the need of the learners to feel satisfied with the benefits of the gamified m-learning application and to develop a future desire to continue using the m-learning product. This is also in accordance with Cheng et al.'s (2020) and Akel and Armağan's (2021) studies.

In the end, it can be concluded that the findings from this study show that less effort in using the effective educational product is very much sought after. Additionally, embedding progressive game and gamification items increase the sense of entertainment gained through the usage of m-learning. Hence, educators should take the opportunity in utilizing the characteristics of game elements in designing effective activities that will increase the enjoyment of online learning.

Contributions

Theoretically, this research contributes to the body of knowledge in three different aspects. First, it extended the use of the ECM by Bhattacherjee (2001), in the context of a gamified m-learning application. This is in line with recent studies that had successfully proven the significance in extending the ECM, in the context of exploring the users' continuance use intention towards a gamified mobile application. For example, T. Wang et al. (2021) combined ECM with self-determination theory (SDT) for a gamified mobile health (mHealth) application, while Ünal and Güngör (2021) implemented the ECM with the Theory of Planned Behavior (TPB) to learn English through a mobile-assisted language learning (MALL) using the gamified m-learning application, namely, Duolingo.

Second, the present study expanded the literature by revealing the critical role of technology pre-acceptance mechanisms or, in other words, explanatory elements on the continuance use intention of a technological product. In support of the previous work by Tam et al. (2020), which also implemented Venkatesh et al.'s (2012) UTAUT2 model as supplementary factors for post-acceptance influences discovery, it was also proven in this study that it can unfold the link between the features of initial adoption that may influence the continuance intention to use a gamified mobile application. However, it is revealed that the additional variables selected should be applied depending on the nature of the technological product used, research situation or time frame, population background, and culture. Lastly, due to the revelation of mediating effect in this study, it also offers a comprehensive understanding of the mechanism that enriches the m-learning application usage apart from complementing prior studies, such as Y. T. Wang and Lin (2021), Ünal and Güngör (2021) and Chang (2022), that simply focus on the direct links of variables without highlighting the role of satisfaction as mediator.

In terms of the managerial contribution aspect, the study may provide insight into the HEI's academic development and management. The academic development and management department usually consist of the products' developers, designers, content administrators, and decision-makers. They may be able to implement gamification elements into the m-learning application which correspond to the mechanics, dynamic and aesthetic aspects (i.e., MDA gamification framework) accordingly, corresponding to van Elderen and van der Stappen's (2019) literature review study. This will enhance learning strategies for education, learners' achievement, participation, and motivation as suggested by Carrión Candel and Colmenero (2022).

Parallel to the results of this study, the digital learning department should refine its gamified m-learning application in terms of: (i) gamification items, (ii) products' ability or functionality, and (iii) user-friendly operation. In the quest to provide a holistic approach towards ensuring the success of the m-learning application in the institution, the developers should also consider the availability of the application in all operating systems (OS) or platforms (e.g., iOS). Although this reflects the factor of facilitating condition, which was discovered as insignificant in this study, earlier studies of technology acceptance by Seethamraju et al. (2018) and technology continuance use by Kamarozaman and Razak (2021) demonstrated its importance.

Limitations and Future Research Directions

The research suffers from three limitations. First, due to performing a correlational cross-sectional study, there is a lack of complete understanding of the dynamics among individuals' perceptions. Therefore, it is recommended that such research perform longitudinal studies instead, which enable researchers to better grasp the dynamics of the constructs over time. Second, the sample used in this research was limited to three types of diploma programmes in one university (i.e., UTHM), which did not include the other programmes (e.g., mechanical engineering, science, and electrical engineering). In that case, it is recommended to include respondents from other diploma programmes, resulting in an in-depth analysis. The last limitation concerns the sample size, or the final number of responses analysed. Further research is needed to support the generalizability of the findings in this study by considering larger populations from all programmes.

An additional suggestion would be applying factors to the prediction model that are related to gamification design elements or features of the product (e.g., object, mechanics, interface) which may contribute to the discovery of effective gamified m-learning application designs. The next suggestion would involve institutional leaders should provide 'transfer-of-technology' workshops that will prepare their educators to implement the institutions' gamified teaching and learning tools and protocols for guided use of mobile devices in learning activities. Finally, should there be a seasonal cycle of COVID-19 as there is with many other viruses, the greater the need for faculties to design an effective approach to entice educators and learners towards applying new learning technologies?

Conclusion

During the COVID-19 outbreak, educational applications have supported many learners in their academic journeys (Butler et al., 2021; Crompton & Burke, 2018). Enabling them access to online learning and engaging in synchronous conversations with other individuals (Camilleri & Camilleri, 2021, 2022). This shows the importance of online approaches in connecting educators with learners. Now, in the post-pandemic era, scholars are beginning to wonder about the existing learners' interest in continuing to use the digital learning tools they had previously used during the pandemic times. Therefore, a continuance use intention topic is essential in the quest to encourage the students to continue acquiring knowledge and for educational platforms to retain users. Based on the integration of ECM and UTAUT2, this study established a theoretical model of gamified m-learning application continuance use and validated the proposed research model.

As expected, continuance use intention is positively influenced by explanatory elements from the pre-acceptance model, excluding social influence and facilitating condition factors that were heavily influenced by the COVID-19 pandemic situation in Malaysia at the time this research was conducted. Due to that situation, where teaching and learning sessions were ordered to be performed virtually or online, students were not able to be influenced by their peers, educators, and institution, as well as having to depend entirely on themselves to facilitate the condition of mobile application usage. Dovetailing with the previous literature, satisfaction has been found to mediate perceived usefulness with the continuance use intention. This phenomenon is seen to be consistent with the characteristics of users in general, where there is a need for them to feel satisfied with the benefits acquired from product usage. Apart from that, some of the limitations have been highlighted, as well as providing suggestions for future research related to m-learning.

Overall, this study has successfully identified the determinants that impacted gamification-based m-learning application continuance use intention among Malaysian HEI learners. Hence, the information may benefit the m-learning developers and stakeholders in the HEI to produce effective gamified learning resources. The m-learning application should now be the ultimate focus in HEIs as it is not just a piece of technology but an indispensable tool that allows educators to interact with the learners. Compared to other e-learning resources, a mobile application is considered to have more advantages as it plays the role of a "connection generator". This is because it provides portable, convenient, and interactive opportunities that allow learners to interact with the institutions' academic content on an ongoing basis.

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APPENDIX

SURVEY INSTRUMENT

Construct	Code	Item
Perceived Usefulness (PU)	PUP1	The Kingdom Quizzes application increases my academic productivity.
	PUT2	The use of Kingdom Quizzes application enables me to solve academic assessment (quiz) faster.
	PUT3	The Kingdom Quizzes application assists me to study efficiently.
	PUU2	The Kingdom Quizzes application enables me to improve my chance in completing academic tasks (e.g., quick formative assessment, self-assessment, peer assessment, revision) due to the concept of portability.
	PUU3	Overall, the Kingdom Quizzes application is advantageous for my learning due to the mobility concept in executing quizzes.
Perceived Ease of Use (PEOU)	PEOUI2	I interact smoothly with the Kingdom Quizzes application while playing the strategy games.
	PEOUI3	I easily understand how to interact with the Kingdom Quizzes application when performing quick formative assessment (quiz).
	PEOUI4	I easily understand how to interact with the Kingdom Quizzes application when playing the strategy game.
	PEOUI5	I do not have the need to think too much on ways to use the Kingdom Quizzes application due to the user-friendly attributes of the application (e.g., application navigation, functions provided).
	PEOUE1	It is easy for me to learn using the Kingdom Quizzes application.
Social Influence (SI)	SIE1	Lecturers/Educators are helpful in the usage of the Kingdom Quizzes application.
	SIO1	My learning institution encourages the use of the Kingdom Quizzes application.
	SIO2	In general, my learning institution agrees with the use of the Kingdom Quizzes application.
	SIN1	I use the Kingdom Quizzes application because my coursemates are using it.
	SIE2R	Lecturers/educators do not agree with the use of the Kingdom Quizzes application for my learning.

Construct	Code	Item
Facilitating Conditions (FC)	FCK1	I have the required knowledge to use the Kingdom Quizzes application due to the provided user guide video and document.
	FCO2	When facing with technical difficulties that are related to my current mobile device, the Kingdom Quizzes application is also supported by other medium of operation (e.g., android tablet, personal computer or notebook supported with third party software).
	FCT1	I can seek technical assistance from my lecturer/educator or applications' administrator when experiencing difficulties while accessing the Kingdom Quizzes application.
	FCI2	The learning institution prepares mobile network/internet that supports (e.g. stable, sufficient) the usage of Kingdom Quizzes application to be accessed around the campus or college.
	FCO1R	The Kingdom Quizzes application is not compatible with technologies (e.g. OS Android, device) that I am currently using.
Perceived Enjoyment (PENJ)	PENJE1R	I do not enjoy the quiz module in the Kingdom Quizzes application.
	PENJE2R	I do not enjoy the game module (tower defence game) in the Kingdom Quizzes application.
	PENJF1R	It is not enjoyable to use the Kingdom Quizzes application.
	PENJI1	I feel that the elements such as rules, rewards, score, rank in the leaderboard, virtual prize in the quiz module of Kingdom Quizzes application is interesting.
Satisfaction (S)	SD1R	I am not satisfied with the limited game level on the tower defence game in the Kingdom Quizzes application.
	SD2	I am satisfied with the flexibility of the time span given in completing the questions in the quiz module in the Kingdom Quizzes application.
	SI1	I feel positive towards the use of the Kingdom Quizzes application.
	SS2	I am satisfied with the output (e.g., completed quiz, revision session, mark and ranking of the students' progress, game session) achieved when using the Kingdom Quizzes application.
	SS3	My lecturer/educator had made the right decision choosing the Kingdom Quizzes application as a tool for students to perform quick formative assessment.
	SS1R	I am unsatisfied with the overall experience of using the Kingdom Quizzes application.
Confirmation (C)	CP1	The benefits delivered by the Kingdom Quizzes application are better than I expected.
	CP3	Overall, my expectations throughout using the Kingdom Quizzes application are fulfilled.
	CS1	The quiz module in the Kingdom Quizzes application is better than expected.
	CS1a	The game module in the Kingdom Quizzes application is better than expected.
	CS2	The functions provided in the Kingdom Quizzes application were carefully thought by the product developer as expected.
	CU1R	The experience while using the Kingdom Quizzes application is worse than expected.

Construct	Code	Item
Continuance Use Intention (CI)	CIR1	I recommend others to use the quiz module in the Kingdom Quizzes application for peer assessment throughout their learning.
	CIR1a	I recommend others to use the quiz module in the Kingdom Quizzes application for self-assessment throughout their learning.
	CIR2	I recommend others to also play the game module in the Kingdom Quizzes application for fun.
	CIU1	I intend to proceed with using the Kingdom Quizzes application for future quizzes or on other subjects.
	CIU4R	I do not intend to frequently use the Kingdom Quizzes application in the future.

AUTHORS

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ATTRIBUTES OF BLENDED LEARNING ENVIRONMENTS DESIGNED TO FOSTER A SENSE OF BELONGING FOR HIGHER EDUCATION STUDENTS

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ABSTRACT

Aim/Purpose	This article seeks answers to the following: (1) What describes a 'sense of belonging', inclusiveness, and well-being for students? (2) Which aspects of blended learning, synchronous and asynchronous, promote students' 'sense of belonging'? and (3) What are the state-of-the-art best practices for creating inclusive curriculum design for blended learning?
Background	For university students, experiencing a strong 'sense of belonging' with their learning communities is a reliable predictor of academic adjustment and program success. The disruption to usual teaching modes caused by the COVID pandemic has diminished opportunities for social engagement among students and their teachers, intensifying the need to encourage students' belongingness as being ever more important.
Methodology	This article surveys the literature, pre- and post-COVID, using two complementary search techniques: (1) a systematic scoping review, a top-down strategy, and (2) snowballing, a bottom-up approach, seeking the answers to the three research questions above.
Contribution	The synthesis presented in the paper provides answers to these questions influenced, in part, by the Community of Inquiry framework and the Universal Design for Learning guidelines. Further, based on our findings from this investigation we offer a set of salient attributes of best practices in designing curriculum for blended learning environments, that is inclusive and fosters a sense of belonging for higher education students

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Findings	We discovered that belongingness is different for various cohorts. Further, many interventions to improve student wellbeing, and learning experiences on and offline, were built around social, teaching, and cognitive presences. Additionally, our investigation found that blended learning, regardless of the proportion of online versus offline instruction, was generally a positive influence on academic outcomes and student learning.
Recommendations for Practitioners	The set of attributes presented offers practical and helpful approaches to improve curriculum design to promote higher education students' sense of belonging.
Recommendations for Researchers	We highlight the lack of specificity in the literature regarding synchronous versus asynchronous learning pedagogy that promotes inclusiveness and a sense of belonging, and we detail our plans for future work will attempt to address this omission.
Impact on Society	As a result of the COVID pandemic, many higher education institutions made a sudden and rapid transition to online learning exclusively. As institutions start the move back to more traditional modes of learning, this paper highlights the considerations to be made in using blended learning environments.
Future Research	Our plans include seeking student and academic advice and feedback on approaches that foster a sense of belonging for higher education students.
Keywords	sense of belonging, blended learning, community of inquiry, higher education, universal design for learning

INTRODUCTION

The advent of the digital age has been evidenced by the steady incorporation of transformational technologies within our daily lives, and not least in its progress, has been its penetration into educational environments. These technologies have been pervasive and have impacted teaching pedagogies, learning environments, and aspects of access (Adel & Dayan, 2021; Bredenkamp, 2015; Cochrane & Narayan, 2018; Irvine et al., 2013). Further, whilst educators navigate the array of opportunities and challenges afforded by increased abilities to acquire and transmit digital information, the arrival of the COVID-19 pandemic has disrupted digital assimilations, and often hastened earlier than planned adoptions (Fabrey & Keith, 2021; Giray, 2021; Hehir et al., 2021; Mulrooney & Kelly, 2020).

Internationally, educational institutions' reactions to the COVID health crisis have been very varied, from some making no response to many universities adopting alternate delivery modes, particularly leveraging upon online curricula (Crawford et al., 2020; Farnell et al., 2021; Gupta et al., 2020). Nearly 1.6 billion students worldwide have been impacted by the sense of unease and uncertainty brought by the pandemic (United Nations, 2020), reporting that they feel "isolated, abandoned, depressed" (United Nations, 2021). Regardless of the institutional response, it is incumbent on academics to address their students' disconnection with their peers, subject content, and staff by creating a learning environment that particularly fosters inclusion, a 'sense of belonging', and wellbeing (Doolan et al., 2021; Farnell et al., 2021). Pre-pandemic, many institutions engaged actively in programs designed to promote their students' sense of connectedness as a strategy for improving learning outcomes, as learners with a strong sense of belonging are more persistent and satisfied with their studies, and these students achieve generally better academically (Delahunty et al., 2014; Peacock et al., 2020; Sax et al., 2018; Spencer et al., 2020; Thomas, 2012; Thomas et al., 2014). Given learners' disquiet and unease brought about by the pandemic, it is ever more important to promote students' sense of belonging in their changed learning environments.

A sense of belonging is created when students feel included and connected to a group, class, subject, and institution (Armellini et al., 2021; Garrison, 2017; Larcombe et al., 2015; Metzger & Taggart, 2020; Peacock & Cowan, 2019; Wilson et al., 2018). Prior to the pandemic, considerable literature focused on gender, cultural, and student disabilities (Baik et al., 2019; Smucker, 2022). However, there has been less of a focus on how the curriculum could be more inclusive for students generally, through content delivery, assessment, and feedback. Institutional responses to the pandemic have seen an acceleration towards blended learning environments, being various synchronous and asynchronous mixes of online teaching and learning with face-to-face campus-based activities. The difficulty for educators is how to create a curriculum that best supports their students' sense of belonging, particularly being mindful that one size does not fit all. An inclusive curriculum takes into consideration the needs of differing student cohorts with various social, cultural, linguistic, educational, and physical/psychological needs who are often physically distant from their peers and/or the university campus. Therefore, the challenge in designing an inclusive curriculum is ensuring the provision of content, pedagogy, and assessment methods through access and opportunities for all students (Smucker, 2022) whilst capitalizing on the advantages of both face-to-face and online teaching (Law et al., 2019).

During the pandemic, our students were offered dual mode classes, being a mix of campus-based face-to-face teaching (f2f) with synchronous online participation by remote students; they participated in blended learning environments where online learning materials and activities were part of the subjects' requirements. Like others worldwide, our students reported in feedback that they felt isolated and disconnected from their peers, subject content, and staff. As educators, we asked ourselves "How can we build a 'sense of belonging' for higher education students through an inclusive curriculum design in a blended learning environment?". In searching for an answer, we decided to undertake a review of the educational literature for insights into instances, successful or otherwise, where attempts had been made to address students' sense of belonging, particularly where opportunities and support were being delivered online. We set about investigating the practice, pre-and post-COVID, seeking to identify the salient features of inclusive curriculum design that is student-centered, flexible, and supportive of student wellness, with a particular focus on blended forms of teaching and learning that capitalize on the affordances of digital technologies. Through the identification of successful practices in the literature, we hoped to arrive at a set of implementable guidelines for academics that help to address the challenges of designing a curriculum for blended learning environments that promotes inclusivity, accessibility, and wellbeing for their students. The following section describes the methodology adopted to conduct this investigation.

METHODOLOGY

As educators, our primary interest is in gaining deeper insights into how the curriculum could be more inclusive for students in the higher education classroom, particularly through pedagogical approaches. In this study, the term curriculum includes content delivery, assessment, feedback, online interaction, and technological platforms. As descriptors of blended learning abound, we include synchronous and its antonym 'asynchronous' learning situations. As the starting point, our research question of "how can we build a 'sense of belonging' for higher education students through an inclusive curriculum design in a blended learning environment?" needed to be decomposed further. The tripartite composition of the research question, being themed around 'a sense of belonging', inclusive curriculum design, and blended learning environments, was delineated into the following more specific questions for investigation. Within the higher education sector:

(1) What describes a 'sense of belonging', inclusiveness, and well-being for students?

(2) Which aspects of blended learning, synchronous and asynchronous, promote students' 'sense of belonging'? and

(3) What are the state-of-the-art best practices for creating inclusive curriculum design for blended learning?

These questions led to the research themes – a sense of belonging, blended learning, higher education, and curriculum – listed in Table 1, together with various synonyms and descriptors of student cohorts to guide our searches of the literature. An initial exploratory search of the themes using the ERIC ProQuest in September 2021 resulted in the following candidate papers for each category: sense of belonging = 27,128, blended learning = 18,556, curriculum = 174,398 and higher education = 467,092. To address our research question and optimize our search outcomes, we chose two very different, yet complementary, search strategies. The first strategy employed was a systematic scoping review, a top-down approach that filters through large data repositories to find exact matches to the selected inclusion criteria (Peters et al., 2015; Tricco et al., 2018). This method returns a restricted set of records, whereby each result must include a descriptor of each of the three research themes of Table 1, together with a relevant cohort label, returning the intersection of all four criteria. Being cautious about the restrictive nature of the systematic scoping review results, a second 'snowballing' method was selected to independently explore each of the three research questions and their various intersections with each other. Snowballing is a bottom-up, broad-brush approach, useful for unearthing insightful works that would be discarded by the narrowing search strategy of the systematic scoping review. Details on the two search methods follow.

Table 1. Keywords for database queries chosen to mirror the research question's themes

RESEARCH QUESTION THEMES			COHORT DESCRIPTORS
Sense of belonging	Blended learning	Curriculum	Higher education
sense of belonging	blended learning	curriculum	higher education
belonging	e-learning	curricula	college
belongingness	hybrid	curriculum development	university
feeling to belong	eLearning	curriculum relevance	post-secondary
inclusiveness	electronic learning	content delivery	postsecondary
inclusion	synchronous	assessment	undergraduate
wellness	asynchronous	feedback	postgraduate
	dual	online interaction	
		technological platforms	
		pedagogical approach	

Systematic Scoping Review Strategy

Systematic scoping reviews are prescribed for researchers interested in identifying characteristics amongst the available evidence, for clarification of definitions and concepts within a field, and for identifying gaps in the knowledge base (Munn et al., 2018; Peters et al., 2015). In such reviews, the decision-making is carried out by at least two researchers and the search strategy is intended to be explicit and transparent through the adoption of documented search terms and the use of standardized data extraction tools. This scoping review has been guided using the prescribed steps: Identification, Screening, Eligibility, and Inclusion, as detailed in Peters et al. (2015), being a revised version of the PRISMA approach that is used globally for more stringent, standardized systematic clinical reviews (PRISMA, 2020; Tricco et al., 2018).

As detailed by Peters et al. (2015), the Identification stage requires exploration using keyword searches in the title, abstract and index terms of articles through querying international education databases. To construct the search queries, we used the Boolean operations of "OR" and "AND"; "OR" was used between all terms within each column of Table 1, while "AND" joined all columns into the query across Table 1. In the Screening phase, all results were sorted into those that were peer-reviewed, in English (translations accepted), involving post-secondary students, including graduates and postgraduates of any discipline, and published post-1990 (after the appearance of web servers and browsers). We chose this relatively early publication date to capture any works relating to possible seminal articles or early insights into aspects of the curriculum for encouraging students' sense of belonging that was supported by online technologies. Results of searches outside of these criteria (shown in Table 1), along with duplicate records, were discarded. Next, in the Eligibility stage, the limits of the search are more strictly defined through a selection of appropriate databases for querying and deciding a set of a priori inclusion and exclusion criteria to guide keywords (Peters et al., 2015). Discussions between the authors fine-tuned the inclusion criteria, so that literature identified from all sources would necessarily have foci on: (1) the social aspect of belonging and disregarding research that solely concentrated on physical fitness or physical wellness; (2) differing learning environments where digital technologies were used and particular interest on comparison studies of on- and off-line practices; and (3) pedagogical practice and ignoring texts that solely related to institutional matters such as administration or recruitment or whole of institute approaches focused on administrative matters.

The leading, internationally recognized ERIC (Education Resource Information Center) database was chosen for its over 1.6 million records of educational literature and resources (ERIC, 2021). Hosted by the U.S. Department of Education, ERIC has two independent search interfaces, EBSCO and ProQuest, that were used separately in the data collection for this study. For the final Inclusion step, sources were rechecked for relevance and full texts were read to identify the purpose of each study and to categorize the study's design and the methods used.

Snowballing Strategy

'Snowballing' or 'chain-referral' sampling is a non-probabilistic, "step-by-step" technique (Biernacki & Waldorf, 1981; Wohlin, 2014). When undertaking snowballing, the foremost objective is to identify a representative sample of the relevant research, yet the chance of achieving a true set is strongly influenced by the decisions made at the beginning of the search. To optimize success, Wohlin (2014) recommends commencing snowballing with seminal works and highly cited materials before undertaking a set of backward and forward iterations.

For this strategy in our investigation, Google Scholar (see https://scholar.google.com/intl/en/scholar/about.html) searches around the key terms sense of belonging, inclusiveness, and blended learning searching for evidence relating to the curriculum including pedagogical approaches, assessments and feedback methods across delivery modes were undertaken to garnish sets of possible articles, whose contents were then examined for relevance and significance to the research questions. Pertinent articles were 'snowballed' by scrutinizing their reference lists for similar relevant research undertaking numerous backward iterations. Most importantly, snowballing allowed us to step forward in time by checking the citations of useful articles, in order that academic conversations, insights, and sometimes consensus around our research questions could be followed. Thus, a bank of research was collected around each theme and their intersections contributing to this paper. The literature identified through the two search strategies, systematic scoping review and snowballing, was collated and synthesized for reporting in the following section.

Results

For the systematic scoping review search, the EBSCO and ProQuest interfaces were queried independently with all search terms listed in Table 1. During identification, the preliminary searches of abstracts, titles, and article keywords in September 2021 returned 28 results, and 59 results respectively. A flowchart summary of the systematic scoping review process, and its four stages, is illustrated in Figure 1, culminating in 25 papers identified for inclusion in the study. For completeness, these results are listed in the Appendix where the context, learning setting, and involved participants for each article are supplied.

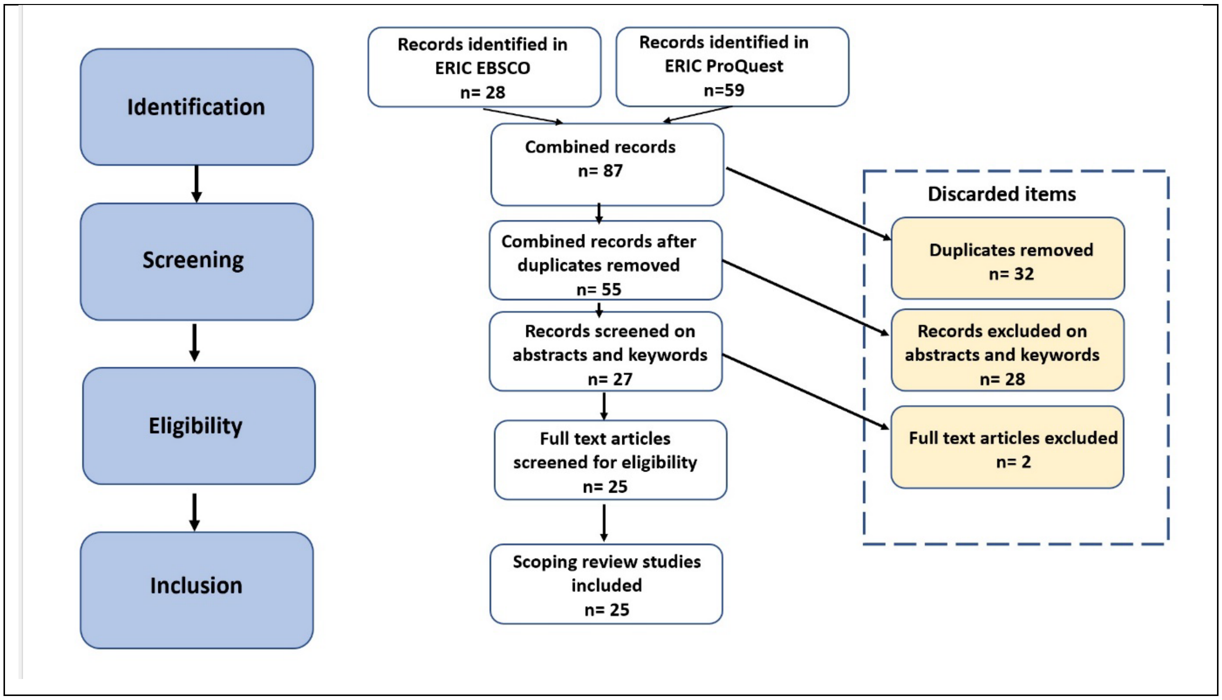

Figure 1. Flowchart for search decision process of keyword searches (Table 1) using EBSCO and ProQuest databases

By its nature, prescriptive scoping reviews funnel down to a small set of articles that may or may not illuminate the research being investigated. In our case, although 25 articles were discovered using our search terms in Table 1, there were few insights provided in addressing our research questions.

To gain a broader understanding, we decided, through snowballing, a separate search of higher education papers on each of our three research themes: a sense of belonging, blended learning, and inclusive curricula. As a result, the significant seed papers that guided our searches were identified for each theme. Four articles initiated our search around 'Sense of belonging' – CAST (2021), Garrison (2017), Malone et al. (2012), and Peacock and Cowan (2019) (see reference list with the prefix 'a'). Similarly, we found four papers – Cunningham (2014), Hastie et al. (2010), Nortvig et al. (2018), and Raes et al. (2020) – that were seeds for snowballing the 'blended learning' theme (see reference list with prefix 'b'). Our third snowballing exercise around 'curriculum' commenced with two articles – Bower et al. (2015), and Zydney et al. (2019) (see reference list with prefix 'c').

Subsequently, a pool of 117 documents was collected from the snowballing strategy and these studies were amalgamated with the 25 studies identified by the systematic scoping review (listed in the Appendix). All texts were explored for answers to each of the research questions, with the combined insights from both searches presented here under the themes: sense of belonging, blended learning, and inclusive curriculum.

Sense of Belonging

In addressing the first question, "What describes a 'sense of belonging', inclusiveness, and wellbeing for students?", we found that identity construction is an ongoing process defined through the formation of interpersonal attachments with their classmates and institutional communities, on- and off-line (Baik et al., 2019; Delahunty et al., 2014; Diep et al., 2017; Sax et al., 2018; Spencer et al., 2020; Thomas, 2012). As such, many higher education providers now adopt a 'whole of institute' approach to bolster students' confidence and sense of connectedness with the aim to enhance student-learning outcomes (Hughes & Spanner, 2019; Molyneaux et al., 2017; Scobie & Picard, 2018; Wilson et al., 2018). Although such strategies are not the focus of this investigation, they pivot on the point that "academics and the curriculum are the only guaranteed points of contact between students and the university" (Hughes & Spanner, 2019, p. 26) and the two factors that most strongly impact student engagement are their learning experiences and social networks (Armellini et al., 2021; Cole et al., 2021; Wilson et al., 2018).

Given the importance of social connectedness and a 'sense of belonging' for student learning, the search around this theme sought definitions of belongingness, looking for its measures and evidence of its impacts, particularly in online and blended learning environments. As pointed out by Metzger and Taggart (2020, p. 231) summarizing Malone et al. (2012), "Belongingness is a psychological construct characterized by value, fit, and meaningful engagement in person-to-person, small group, and larger social contexts". Attempts to measure a person's achieved belongingness, rather than their need to belong, have been made by Malone et al. (2012) using the 12-item survey General Belongingness Scale (GBS). The GBS uses six items to assess the level of acceptance and inclusion within a group and six items (reverse-scored) to indicate rejection and exclusion. The GBS has been broadly adopted in differing work, social and educational settings (e.g., Metzger & Taggart, 2020; Yildiz, 2017). More specifically, student belongingness is defined by Spencer et al. (2020, p. 199) as "the extent to which students feel accepted, respected, included, and supported by others in an academic setting".

Yorke (2016) devised a 16-item Belongingness Engagement and Self-Confidence Survey (BESS) to gauge a student's sense of belongingness with their institution, their perceptions of academic engagement, and their overall self-confidence. The BESS instrument was trialed at 13 UK universities across three disciplines with large differences in the activities undertaken at each site and student population compositions. The involved institutions found the BESS application to be generally helpful for its separate scores for belongingness, engagement, and self-confidence, especially when BESS was applied pre- and post-local interventions. Yorke (2016, p. 163) examined all data across these 13 universities to investigate the impact on belongingness, engagement, and self-confidence of six characteristics within the data: male, first in the family, under 20 years of age, white British, UK domicile, and low adverse circumstances. Several patterns relating to the three scales emerged: a sense of belonging was impacted by ethnicity and circumstantial disadvantage; engagement was influenced by gender and age; and self-confidence was affected by gender, age, disability, and position in family or family experiences in higher education.

Elsewhere, similar patterns are mirrored in the literature (e.g., Sax et al., 2018). Efforts to create inclusive classrooms have often been fraught with difficulty given the diversity among learners, including minority groups of color, gender, sexuality, first-in-family, mature-age, poorer socioeconomic backgrounds, disability, regional, and remote learners (Delahunty et al., 2014; Delaney & Brown, 2018; Dinmore, 2014; Ibáñez-Carrasco et al., 2020; Lin & Nguyen, 2021; Osei-Kofi et al., 2004; Pearson et al., 2019; Sathy & Hogan, 2019). For different ethnic groups, various authors report that students' 'sense of belonging' and feelings of inclusion wax and wane over time impacting their learning (Adel & Dayan, 2021; Cureton & Gravestock, 2019; D. R. Johnson et al., 2007; Lin & Nguyen, 2021; Rainey et al., 2019). Furthermore, students with physical or mental impairments often find tertiary study quite challenging as it can have a negative impact on their wellbeing, causing anxiety and stress (Orygen, 2017; Pearson et al., 2019). Thus, the importance of inclusion for all students has been widely recognized and the study of strategies to encourage students' confidence has been incorporated into teacher training programs in Brazil (Aparecida do Nascimento dos Santos et al., 2016; Quevedo, 2011), Chile (Fermín-González, 2019), Finland (Seikkula-Leino et al., 2012), Taiwan (Yeh, 2010), and USA (Graziano & Bryans-Bongey, 2018).

Amongst the approaches employed to bolster students' 'sense of belonging' and wellbeing investigated by our searches are strategies influenced by Garrison's (2011, 2017) well-known Community of Inquiry framework, presented in Figure 2, where a student's educational experience occurs at the confluences of their social presence with teaching and cognitive presences. Garrison (2017, pp. 23-24) defines each presence. *Social presence* is the ability of participants to identify with a group, communicate purposefully in a trusting environment, and develop personal and affective relationships progressively by way of projecting their individual personalities. *Cognitive presence* speaks to intent, process, and learning outcomes and the extent to which learners can construct and confirm meaning through sustained reflection and discourse in a critical community of inquiry. *Teaching presence* is the design and facilitation and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes.

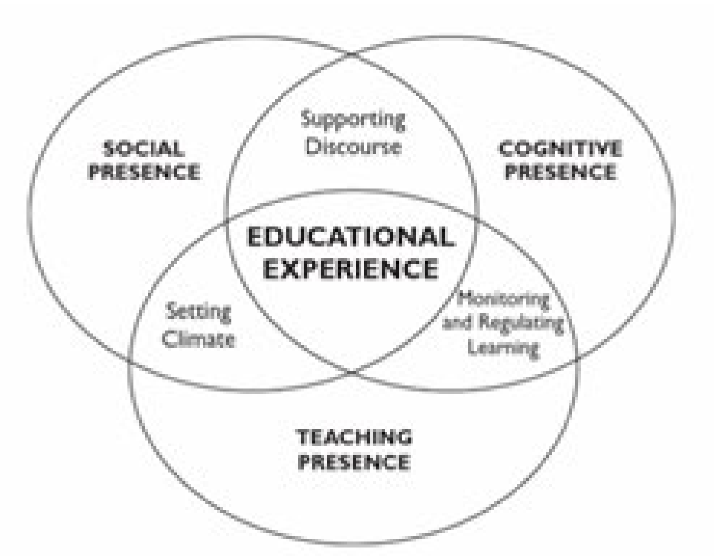

Figure 2. The Community of Inquiry framework with descriptions of presences as defined by Garrison (2017, pp. 23-24)

For more than 20 years, the Community of Inquiry framework has informed the action-research of many when planning their interventions to improve student outcomes (Castellanos-Reyes, 2020) and as noted in a co-citation analysis by Park and Shea (2020), Garrison's peer-reviewed articles and books ranked the highest in online, distance and blended learning between 2008 to 2017. By incorporating meaningful intersections between the social and cognitive aspects of teaching presences, the Community of Inquiry framework is often used to explain the empirical practice, particularly for online or blended learning, where actors may be in different physical locations (Spring & Graham, 2017). Several such instances were found during searches for this review (Bower et al., 2015; Cunningham, 2014; Delmas, 2017; Heilporn et al., 2021; Law et al., 2019; Stewart et al., 2011; Swan et al., 2012; Swickard, 2021). Also documented in the literature have been institutional responses to the COVID-19 pandemic by moving to online and distance learning, to mitigate its impact on nearly 220 million higher education students worldwide (Doolan et al., 2021; Farnell et al., 2021). These efforts bring into sharper focus the need to support students in their learning, especially in offline and blended learning environments (Giray, 2021; Hehir et al., 2021; Lin & Nguyen, 2021; Milman, 2020; Mishra et al., 2021; Mulrooney & Kelly, 2020).

Blended Learning

In seeking answers to the second research question "Which aspects of blended learning, synchronous and asynchronous, promote students' 'sense of belonging'?", we searched firstly for accepted and meaningful definitions of blended synchronous learning. One of the broadest definitions is that of Spring and Graham (2017) as a "combination of face-to-face and computer-mediated instruction" for use in their thematic search for patterns thereby avoiding possible limitations imposed by other definitions with more specific requirements, like that of Allen et al. (2007), where the proportion of online content delivery is prescribed as between 30% to 79%. Additionally, Müller and Mildenberger (2021) posit that "blended learning is often used interchangeably with terms such as hybrid, mixed-mode or flexible learning", while complexity is added through the use of the term synchronous learning, as opposed to asynchronous learning, which can be decomposed further into live or virtual modes (Chaeruman et al., 2018). To belabor this point, Hastie et al. (2010, p. 11) give 16 permutations of student versus teacher in cyber versus physical classrooms to classify nine different blended synchronous learning modes, before discussing the advantages and disadvantages of each. Based on these definitions, it becomes clear that there is a frustrating variety in how different authors understand and define blended learning, even more so, for blended synchronous learning. We note that much of the literature speaks of blended learning modes without a clear delineation between synchronous and asynchronous activities. For some clarity, we adopt the definition of blended synchronous learning that captures its essence and usage in the literature by Bower et al. (2015, p. 1), being: "Learning and teaching where remote students participate in face-to-face classes by means of rich-media synchronous technologies such as video conferencing, web conferencing, or virtual worlds".

As organizational savings in time and money are among the recognized benefits of synchronous blended/hybrid learning adoption (OECD, 2005; Raes et al., 2020), the relative proportions of face-to-face (f2f) versus e-learning are of interest to researchers, particularly concerning the impacts on student outcomes, engagement, and wellbeing (Bader & Kottstorfer, 2013; Delahunty et al., 2014; Müller & Mildenberger, 2021). Several comparative studies between f2f, blended and totally online (distance) learning have been made to gauge these effects (Bader & Kottstorfer, 2013; Bower et al., 2015; Cossaboon, 2020; Nieuwoudt, 2020; Rhoads, 2020). For students' academic achievements, Mu et al. (2014) undertook a retrospective study of occupational therapy doctoral students from differing modes to find no discernible differences in the results of examinations, clinical tests, and certifications. Likewise, Nieuwoudt (2020), investigating the academic performance of students attending virtual classes, either synchronously or asynchronously, found that total time spent in class was a strong positive predictor, rather than the mode. In contrast, Tripathi et al. (2017) found academic performances of pharmacology students were best in their pure e-learning model, yet when asked students favored the blended version of f2f with online learning.

For a broader view, Bernard et al. (2014, p. 88) report a meta-analysis of achievement outcomes across studies which supports blended learning over pure classroom instruction by about "one-third of a standard deviation ($g^+ = 0.334$, $k = 117$, $p < .001$)", finding the improvement associated with the use of technology for cognitive support rather than for presentation purposes and "the presence of one or more interaction treatments (e.g., student–student/–teacher/–content interaction)". While noting inconsistencies amongst comparison studies of online, blended, and f2f formats, Nortvig et al. (2018, p. 48) summarize that there are "no inherent features of any of the three teaching formats produce either better or poorer learning outcomes for students", stating that reported improvements most likely result from the opportunities afforded by computers to learn independently supported by student-centered asynchronous collaborative learning activities. This is further underlined by the meta-analysis findings of Müller and Mildenberger (2021) who used the blended learning definition of Allen et al. (2007), where the proportion of online delivery content is between 30% and 79%. From their analysis of 21 studies, with 2,505 participants in blended learning versus control of 3,004 undergraduates in traditional courses, they report no discernible effects of reductions in f2f classroom time, noting "of greater importance are how teachers – irrespective of the method of delivery – make their success criteria clear and offer challenge and feedback, coupled with the quality of the interaction among students and between students and teacher" (p. 11).

When surveyed, students resoundingly prefer blended learning over traditional instructional learning (Bader & Kottstorfer, 2013; Milroy et al., 2013; Rhoads, 2020; Tripathi et al., 2017) with a 'sense of belonging' to a learning community associated with greater student satisfaction, social adjustment to university and program persistence (Brodie & Osowska, 2021; Delmas, 2017; Falloon, 2012; G. M. Johnson, 2015; Teo, 2010; Wilson et al., 2018). As pointed out by Raes et al. (2020), different delivery modes better support different learner characteristics, empowering students with some sense of control over their own learning. Various authors have investigated predictors of students' course satisfaction as influenced by several psychosocial influences, being personal confidence, self-efficacy, time management, and organizational skills, social presence and support within peer and learning communities, and the impacts of work, family, and caring responsibilities (Delahunty et al., 2014; Farrell & Brunton, 2020; G. M. Johnson, 2015; Milroy et al., 2013; Peterson et al., 2018). At a large Australian university, 2,776 students across differing disciplines and instruction modes were asked the open-ended question, "What can be done to improve student wellbeing?" (Baik et al., 2019). The theme of many responses (n=161) related to "the importance of fostering a more inclusive and caring sense of community among the student body" and the need for teachers to facilitate and foster teacher-student interactions and peer interactions (n=167). Likewise, Brazilian students were asked for suggestions to improve their blended learning offerings, and "emotional support among students and from the teacher" was seen as an important motivation for students' participation and learning (Quevedo, 2011, p. 198).

As important as a 'sense of belonging' is for learning, Bower et al. (2015, p. 2) remind us that in blended synchronous learning environments, "social and emotional connectedness cannot be taken for granted but rather needs to be actively encouraged and fostered by teachers". To this end, several authors note that a 'sense of belonging' needs to be orchestrated for students participating online (Delahunty et al., 2014; Farrell & Brunton, 2020; N. Johnson et al., 2010) with this being particularly important for students from non-traditional backgrounds (Ibáñez-Carrasco et al., 2020; Thomas et al., 2014). To promote social interactions and belongingness, staff need to investigate and recognize strategies, like implementing communication protocols, providing multiple means for interaction, embedding collaboration into assessment, and providing different feedback methods (text, audio/video) (Delahunty et al., 2014; Farrell & Brunton, 2020; Kandemir & Kiliç Çakmak, 2021; Swickard, 2021; Thomas et al., 2014; Weiser et al., 2018).

While educators move to blended learning environments to improve student belongingness and engagement, efforts can be impeded by technical problems with equipment, poor skill sets of academics, and student unfamiliarity with platform interfaces (Cole et al., 2021; Delahunty et al., 2014; Falloon, 2012; N. Johnson et al., 2010; Lakhal et al., 2020; Ørngreen et al., 2015; Teo, 2010). For the instructor, this adds to the cognitive load of trying to juggle equivalence in interactions for on-and-offline cohorts whilst coping with connection issues and providing technical guidance (Bower et al., 2015; Nortvig, 2013; Raes et al., 2020). Several authors have emphasized the need for instructors to be trained and have real-time technical support, possibly from a teaching assistant or skilled colleague (Dinmore, 2019; Krutka et al., 2019; Lakhal et al., 2020; Spencer et al., 2020; Sun & Chen, 2016; Swickard, 2021). Equally, students can be frustrated with connection and timing issues, and therefore need adequate training with the IT tools and platforms being used (Cunningham, 2014; Lakhal et al., 2020; Spencer et al., 2020; Zydney et al., 2019). Finally, Brodie and Osowska (2021, p. 8) highlight another concern for students, noting "widely used automated messages either in the form of generic emails and university news seem to work against a sense of belonging among online students, making them, rather, feel disenfranchised (Read et al., 2003)."

INCLUSIVE CURRICULUM

Commencing our investigation for the third research question "What are the state-of-the-art best practices for creating inclusive curriculum design for blended learning?", we searched across all learning settings for inclusive curriculum descriptions and for well-founded approaches to build students' sense of belonging which have gained broad acceptance. As such, the Universal Design for Learning (UDL) guidelines have been in use since 1984 and are widely applied (e.g., Ministry of Education, New Zealand, 2021; University of New South Wales, Australia, 2021; in the United States, Moore et al., 2018). UDL has been advocated for wider use in higher education (Coy, 2016; Dinmore, 2014), yet Fornauf and Erickson (2020, p. 192) caution in their literature review, that UDL implementation in higher education is impeded by "instructional methods and environments".

Originally a strategy to improve access to learning for disabled students, UDL guidelines "offer a set of concrete suggestions that can be applied to any discipline or domain to ensure that all learners can access and participate in meaningful, challenging learning opportunities" (CAST, 2021). The UDL framework was crafted using insights from neurological studies as to (a) how students engage, (b) the differing ways in which students can action and express their learning, and (c) how students relate to the ways learning materials are presented. Using these understandings and as seen in Table 2, the UDL guidelines are a set of practical strategies designed to improve equitable access to information for all students, build knowledge and internalize to empower learners through the provision of multiple means of engagement, materials representation, and action and expression. Amongst the guidelines are suggestions like offering alternatives for visual information, using multiple media for communication and optimizing access to tools and assistive technologies. Although the origins of the UDL guidelines predate the digital era, they incorporate suggestions and strategies listed in the previous section for improving students' sense of belongingness in blended learning environments.

Table 2. Universal Design for Learning guidelines offering concrete suggestions and strategies for all learners (CAST, 2018)

Universal Design for Learning Guidelines version 2.2 Note: Each dot point suggestion can be expanded into further instructional detail in the source document retrieved from http://udlguidelines.cast.org			
	Provide multiple means of engagement	**Provide multiple means of representation**	**Provide multiple means of action and expression**
Access	**Recruit interest** • optimize individual choice & autonomy • optimize relevance, value & authenticity • minimize threats & distractions	**Perception** • offer ways of customizing the display of information • offer alternatives for auditory information • offer alternatives for visual information	**Physical action** • vary the methods for response & navigation • optimize access to tools & assistive technologies
Build	**Sustain effort & persistence** • heighten salience of goals & objectives • vary demands & resources to optimize challenge • foster collaboration & community • increase mastery-oriented feedback	**Language & Symbols** • clarify vocabulary & symbols • clarify syntax & structure • support decoding of text, mathematical notation & symbols • promote understanding across languages • illustrate through multiple media	**Expression & communication** • use multiple media for communication • use multiple tools for construction & composition • build fluencies with graduated levels of support for practice & performance
Internalize	**Self-regulation** • promote expectations & beliefs that optimize motivation • facilitate personal coping skills & strategies • develop self-assessment & reflection	**Comprehension** • activate or supply background knowledge • highlight patterns, critical features, big ideas & relationships • guide information processing & visualization • maximize transfer & generalization	**Executive functions** • guide appropriate goal setting • support planning & strategy development • facilitate managing information & resources • enhance capacity for monitoring progress
Goal	**Expert learners who are**		
	Purposeful & Motivated	**Resourceful & Knowledgeable**	**Strategic & Goal-Directed**

Furthermore, in discerning best practices for inclusive curriculum design in blended learning environments, our literature searches returned many reports of empirical attempts to build students' 'sense of belonging' that were influenced by Garrison's (2011, 2017) Community of Inquiry framework's interactions of teaching presence with student's social and cognitive presences (Cunningham, 2014; Delmas, 2017; Kilis & Yildirim, 2019; Law et al., 2019; Peacock & Cowan, 2019; Watson et al., 2016). Guidance from these practices is examined next through the lens of each presence.

Teaching presence

This presence is further categorized by Garrison (2017) into design and organization, facilitating discourse, and direct instruction. Heilporn et al. (2021) note that good design and organization, through the provision of a well-structured and well-paced course that fully exploits synchronous and asynchronous modes of blended learning, can go a long way to ensuring an inclusive curriculum. Many pedagogical issues can be tackled through adequate preparation of materials (Heilporn et al., 2021; Lopez, 2019), and as Goldwasser and Hubbard (2019, p. 5) highlight "from a policy perspective, the only cost of inclusive classroom pedagogies to individual faculty members are the time costs required to reflect critically on one's pedagogical tools, curricular decisions, and self-awareness/preparedness."

Another aspect of teaching presence is facilitating discourse. In the preparation stages, careful planning and the conscious choice of technology is imperative as technical features will support, and possibly constrain, access to content, communications, and sharing (Farooq & Matteson, 2016; Hehir et al., 2021; Kandemir & Kiliç Çakmak, 2021; Lopez, 2019; Zydney et al., 2019). Consideration also needs to be given to links and interactions between students, teachers, and the content with the scaffolding of online and offline activities ensuring that deliberate connections are made so that interactions with each support and build upon the other (Heilporn et al., 2021; Lin & Nguyen, 2021; Nortvig et al., 2018; Orange et al., 2012).

Various authors provide advice for the direct instruction aspect of teaching presence noting the importance of establishing a strong educator presence as the teacher acts as a role model (Armellini et al., 2021; Hehir et al., 2021; Metzger & Taggart, 2020; Nortvig et al., 2018; Watson et al., 2016; Weiser et al., 2018), stating that instructions regarding roles of the teaching team and students should be clearly explained to create a safe, inclusive learning environment online and offline (Goldwasser & Hubbard, 2019; Heilporn et al., 2021; Kandemir & Kiliç Çakmak, 2021). According to Delahunty et al. (2014), these decisions can strongly impact students' sense of belonging and their engagement, so consideration needs to be given to whether interactions should be voluntary or mandatory, and when and how to give instruction and guidance in skill development, and how to give timely and appropriate feedback. Finer-grained advice from Goldwasser and Hubbard (2019) suggests relating course content to the real world and incorporating life lessons into classes, along with advocating small discussion groups, while Thomas et al. (2014) reported success with video-conferencing lectures.

Social presence

Supporting students' social relations in meaningful learning communities designed to foster coherence between online and offline activities is essential in building blended learning courses (Hehir et al., 2021; Nortvig et al., 2018). Social presence in the Community of Inquiry framework has three types: personal/affective, open communication, and group cohesion (Garrison, 2017). As explained by Watson et al. (2016, p. 56) "Affective expression refers to the sharing of personal beliefs, values, and attitudes; open communication focuses on building a sense of group commitment; and group cohesion refers to learners focusing on common intellectual tasks." In their longitudinal study of nursing students, Metzger and Taggart (2020, p. 233) found various affective strategies to be important in building students' belongingness, being learning names, letters of introduction from their professors, relating personal success stories, and the use of icebreaker sessions. Success with these has also been reported by others (Fabrey & Keith, 2021; Goldwasser & Hubbard, 2019; Kilis & Yildirim, 2019; Sathy & Hogan, 2019; Thomas et al., 2014). Further, the importance of open communication is underlined in online environments due to the "absence of usual meaning-making cues such as gesture, voice tone and interactive immediacy supporting negotiation of meaning and clarification" by Delahunty et al. (2014, p. 247), warn in their review that "how an online instructor reacts is possibly more crucial than their level of involvement in the discussions impacting on socio-emotional well-being perhaps more so than in face-to-face situations." Interestingly, Weiser et al. (2018) found in their three-way comparative study of synchronous learning environments that students using combined voice and video conferencing did not initiate learning interactions with their instructors, whereas those with only voice communication and others in traditional settings regularly did. The authors suggest the differences in behavior were due to a perceived higher risk of social embarrassment for participants when a video was used.

For blended learning, group identity and cohesion are important (Altebarmakian & Alterman, 2019). Student groups need to be created that mitigate or eliminate tokenism (Goldwasser & Hubbard, 2019). Purposeful relevant tasks should be set that are open-ended and collaborative (Delahunty et al., 2014) and a teacher presence 'felt', that is available if needed to keep discussions on track (Altebarmakian & Alterman, 2019; Lin & Nguyen, 2021; Thomas et al., 2014). To this end, discussion protocols in blended synchronous learning environments were welcomed by students, who took on greater leadership roles as facilitators within groups (Zydney et al., 2019) and for online discussion forums, whereas Altebarmakian and Alterman (2019) suggest the use of a nested threaded structure, as opposed to a sequential stream of messages, enabling students to see the overall picture and target their own contributions to conversations. As noted by Thomas et al. (2014), group identity is often maintained by students through Skype and Facebook outside the online teaching environment. Further, O'Brien and Freund (2018, p. 4) suggest that "the effective use of social media could potentially aid social inclusion, encourage active learning and enhance student engagement" and they report upon the lessons learned that social media was a useful scaffold for students' learning, but there was a need for expectations and marking criteria to be made explicit, and for institutional support for its use. Additionally, Forbes (2017) explores the use of social media within a teacher training program for sharing content and supporting collaborations, underlining the need for all to adhere to professional standards and to act in socially responsible ways.

Cognitive presence

This presence contributes to the learning experience of a student through the construction, and confirmation of meaning "through sustained reflection and discourse in a critical community of inquiry" (Garrison, 2017, pp. 23-24). For encouraging students' cognitive engagement through blended learning, Heilporn et al. (2021) investigated successful synchronous and asynchronous teaching practices by interviewing 20 instructors across differing disciplines at four universities in Canada. They report those effective strategies to include interactive learning activities using supportive digital tools, relating content to professional practice and current events, and offering students options in topics, resources, and assessment formats (p. 12). Others underline the importance of providing options in setting up assessments (Coy, 2016; Fabrey & Keith, 2021; Sathy & Hogan, 2019), and embedding collaboration into assessment to promote social interactions (Giray, 2021; Thomas et al., 2014) with a detailed suggestion by Altebarmakian and Alterman (2019, p. 2) to prescribe "an activity where each individual student is tasked with writing a certain section for a final essay on their own and then the group works together to fit each of their individual section together into a larger whole."

Exploring differing assessment types, Gupta et al. (2020, p. 8) tabulate the respective effectiveness and relevance of different modalities for asynchronous and synchronous environments. For example, multiple-choice questions are reliable and cost-effective for examining knowledge but fail to assess complex skill sets adequately, and they are not appropriate for asynchronous testing due to the possibility of cheating. Additionally, the form of feedback is also important (Baik et al., 2019); it should be constructive, in a positive tone, and not single out any one student (Goldwasser & Hubbard, 2019), and it can take on various forms, textual, and/or audio-video (Borup et al., 2015; Dinmore, 2019; Kandemir & Kiliç Çakmak, 2021).

DISCUSSION

In setting out to answer the question "How can we build a 'sense of belonging' for higher education students through an inclusive curriculum design in a blended learning environment?", we determined three research questions and investigated each using two search strategies: systematic scoping review process and snowballing. Here, we discuss our findings in answer to each research question and based on these, we present a set of salient attributes and practices identified in the literature to build students' sense of belonging in blended learning environments, both synchronous and asynchronous, before detailing our conclusions and plans for future work.

WHAT DESCRIBES A 'SENSE OF BELONGING', INCLUSIVENESS, AND WELLBEING FOR STUDENTS?

All students strive to have meaningful engagements with their learning communities and institutions, and those with a strong 'sense of belonging' do better in their social adjustment to university and in program completions. In the past ten years, there have been two broadly accepted survey instruments to measure belongingness: General Belongingness Scale (GBS) in the wider community, and the Belongingness Engagement and Self-Confidence Survey (BESS) for tertiary students. Collated BESS results from across institutions reiterate much evidence from the literature that student belongingness is lower for differing ethnicities, minority groups, and those with circumstantial disadvantages. When investigating reports of practical efforts to improve students' 'sense of belonging', Garrison's Community of Inquiry framework has featured strongly in the literature over the past 20 years. The framework posits that a student's educational experience is influenced equally by three presences: social (inclusive of their relationships with others), teaching, and cognitive. This framework has found application in online and blended learning practices.

WHICH ASPECTS OF BLENDED LEARNING, SYNCHRONOUS AND ASYNCHRONOUS, PROMOTE STUDENTS' 'SENSE OF BELONGING'?

In describing blended learning, some authors were very prescriptive in deciding the proportions of online versus face-to-face traditional learning, while others had broader definitions. Regardless, the results of various meta-analyses suggest the proportion of blended learning, synchronous or not, has little or no effect through to a positive impact on learning outcomes and academic achievements. Rather, the consensus is that blended learning environments offered varied supports for different learner characteristics, thereby promoting student engagement amongst diverse cohorts. Consistently, students preferred blended learning over purely traditional instruction. For students, both blended synchronous and asynchronous learning provide opportunities to interact with their learning communities and develop relationships whilst providing flexibility in their study patterns. Therefore, online environments need to be crafted to foster student social interaction and encourage participation.

WHAT ARE THE STATE-OF-THE-ART BEST PRACTICES FOR CREATING INCLUSIVE CURRICULUM DESIGN FOR BLENDED LEARNING?

Our searches for best practices in creating inclusive curricula led to the widely adopted Universal Design for Learning (UDL) guidelines, which have been in use for over 30 years. The strength of UDL is in its general applicability through practical suggestions of how to provide multiple means of engagement, materials representation, and opportunities for student action and expression, thereby fostering an inclusive environment for all students, irrespective of ability, background, or discipline.

Additionally, in exploring inclusive curriculum design for blended learning, we found that many practitioners undertaking empirical research were referring to the perspective of Garrison's Community of Inquiry framework to guide their efforts in building inclusive learning in online and off-line environments. Much practical "from the chalk-face" advice was offered in these articles that have been collated in our Results section, of which several suggestions mirror individual UDL guidelines.

Yet in our attempt to answer the overarching question of "how can we build a 'sense of belonging' for higher education students through an inclusive curriculum design in a blended learning environment?", we are frustrated on three accounts. Firstly, the UDL guidelines through their history (pre-digital) and nature (all learners in all environments) are too generic; they cannot add detail or specifics for blended learning environments. Secondly, like Raes et al. (2020, p. 286) in their recent review of synchronous hybrid/blended learning, we found that much research from 1990 to September 2021 is "still in its infancy" and further investigations are needed to discover meaningful effects and to discern scalable approaches. Thirdly, we discovered comparative studies between traditional face-to-face, purely online e-learning, and blended learning alternatives, but we found few targeted analyses of best practices for synchronous blended learning, as opposed to asynchronous electronic learning, designed to build students' sense of belonging through inclusive curriculum design.

We have collated our findings of successful practices and present them in Table 3 as salient attributes to build students' sense of belonging through inclusive curriculum design for blended environments, in either synchronous or asynchronous modes. The attributes identified include a holistic view of an inclusive curriculum design incorporating: (1) teaching design and organization, discourse, and directional instructions; (2) social aspects of communication; and (3) assessment and feedback. Note that where reported strategies have mirrored some of the individual approaches listed in UDL guidelines, these approaches have been incorporated into Table 3, where we have used the teaching, social and cognitive presences of Garrison's Community of Inquiry (COI) as a convenient means of presentation and summary. Finally, we note that many of the listed attributes were detailed in reports of action research efforts initiated in response to problematic situations, such as the diversity of student cohorts and more recently, the COVID pandemic. Since many institutions have recently moved to online environments and differing blended learning situations, we anticipate many more accounts of successes or otherwise, shortly.

CONCLUSION AND FUTURE RESEARCH

In presenting Table 3, we acknowledge that the attributes listed are an assemblage of observed practices and features gleaned from the education literature that have found success in promoting students' sense of belonging in blended learning, however not specific to synchronous versus asynchronous situations. In the absence of such detail, Table 3 is a compendium of features and practices rather than a prescriptive 'how to' set of guidelines for blended learning curricula. Nevertheless, we suggest that our compilation offers a useful springboard from which to initiate conversations and stimulate teaching practices and curricula design.

Originally, we set out to discover finer-grained advice specific to blended synchronous learning. Whilst we await reports of more empirical efforts stimulated by responses to the pandemic, we wonder if there is a set of attributes peculiar to blended synchronous learning, or are such attributes simply a facet of best teaching and learning practices that encompass face-to-face, online, and blended modes, synchronous and asynchronous? Does one size fit all? Or have we been distracted by the 'sleight of hand', that is, the assumption that the incorporation of digital technologies into our teaching spaces requires a different sort of teaching practice?

To better refine our position on how we build a 'sense of belonging' for higher education students through an inclusive curriculum design in a blended learning environment, we plan to evaluate and enhance the set of attributes presented in this paper. Through focus groups, we will collect academics' understandings of 'inclusive' curriculum delivery, assessment, and feedback in the subjects they teach; we will ask for their experiences and suggestions in creating a 'sense of belonging' for students, synchronously and asynchronously. As well, insights on technological affordances that academics find helpful in blended course implementation will also be sought. Student opinions on the suitability, or otherwise, of various aspects of curriculum delivery, assessment, and feedback that help them feel included in their subjects, will be collected through focus groups and a survey instrument. Following on from this feedback, we expect to have a better understanding of the curriculum, technological affordances, assessment, and feedback in a blended environment that best promotes our students' inclusion and wellbeing. Guidance from these understandings will inform our teaching practices in the near post-COVID future.

Table 3. Salient attributes to build students' sense of belonging through inclusive curriculum design for blended environments, in either synchronous or asynchronous modes

COMMUNITY OF INQUIRY PRESENCES		
Teaching	Social	Cognitive
Design and organization • emphasize goals and break goals into short-term objectives • prepare materials ensuring well-paced course and activities • build fluencies with graduated levels of support for practice and performance through approaches, strategies, activities, and feedback • vary the methods for response and navigation by providing alternatives to interact with instructional materials and technologies, illustration through multiple media • consider proportions of synchronous vs asynchronous iterations to ensure continual student engagement • plan for group discussion • clarify vocabulary and symbols suing hyperlinks to definitions and explanations • encourage deep learning through explicit relationships between elements and connecting them to previously learned structures and through explicit cross-curricular connections **Discourse** • conscious choice of technology to support communication between teacher and students, and between students, on- and off-line • optimize access to tools and assistive technologies for navigation, interaction, and peer collaboration • offer ways to customize the display of information, both auditory and visual- content, text and fonts, layout, animation, and simulations **Directional instruction** • strong teaching presence where teacher is a role model and guide • relate course content to real world, optimizing for relevance and authenticity • maximize transfer of knowledge and generalization through scaffolds to connect to prior knowledge, mnemonics to help remember, electronic reminders, review, and practice • consideration of whether interactions should be voluntary or mandated	**Personal/affective** • promote expectations and beliefs that optimize motivation using reminders, guides, rubrics, and checklists • relate real-world personal success stories • highlight patterns, critical features, big ideas and relationships • promote understanding across languages and culture using electronic translation tools, online glossaries, use of images and videos • optimize individual choice and autonomy to participate in learning activities • learn names of students through use icebreaker sessions or practice-sharing activities at beginning of semester • regular emails from teaching staff – introduction and touching base **Open communication** • foster collaboration and community through group learning, peer interaction and support and group work • use multiple media for communication including social media and webtools such as discussion forums, animations • teacher presence as facilitator when needed • guide appropriate goal setting and facilitate personal coping skills and strategies through scaffolding with reminders, models, checklists and provide links to external support services • guide information processing and visualization by breaking up information up into smaller units, and progressively releasing it • be aware instructor reactions can be viewed differently by on- and off-line students • use communication protocols • use nested threaded structure for online discussion forums **Group identity and cohesion** • create groups that mitigate tokenism • tasks should be open-ended and collaborative	**Assessment** • offer differing options for assessment providing choices in topics, resources, or assignment formats • vary demands and resources to optimize challenges • use supportive digital tools such as online quizzes and discussion forums • promote active learning through problem solving, role playing, discussions • embed social interaction within assessment task • consider the appropriateness of assessment type for synchronous and asynchronous environments, such as open-ended or problem-based questions are suitable in asynchronous environment whereas time-bound, skill-based assessments, such as oral assessments, need to be synchronously • develop self-assessment and reflection through aids, templates, or charts to recognize a student's own progress **Feedback** • needs to be appropriate to task • needs to be constructive and positive • increase mastery-oriented feedback that emphasizes effort and improvement to encourage perseverance • enhance capacity for monitoring progress using templates to guide quality and completeness, checklists, and rubrics • provide feedback to the entire group and it should not single out a student within a group

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Literature identified in the systematic scoping review is marked with a *

Literature identified as a seed article for snowballing is marked with [a] for 'Sense of belonging' theme, [b] for 'Blended learning' theme, and [c] for 'Curriculum' theme.

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APPENDIX

The systematic scoping review identified 25 papers for inclusion in the study. These results are listed with the context, learning setting, and involved participants for each article supplied.

Overview of studies included in the systematic review using ERIC EBSCO and ERIC ProQuest. The listing is in alphabetical order of the first author. Dark grey shading shows articles found in both database collections, and the grey shading denotes the paper found only by the ERIC EBSCO search. All other papers were discovered using ERIC ProQuest.

No.	Literature	Context, Learning setting and Participants	Purpose	Design and Methods
1	Armellini, C. A., Teixeira Antunes, V., & Howe, R. (2021)	United Kingdom	Examine student perceptions of Active Blended Learning and identify enablers and barriers to successful student experiences.	Thematic analysis of student focus group discussions (n=60)
2	Bader, L., & Kottstorfer, M. (2013)	Austria Masters students studying Global Studies subject at 2 different universities	Article providing an overview of the use of ICT in Global Studies subject compared to other studies and investigate student perceptions.	Mixed methods, analysis of subject deliveries across implementations, online student survey (n=60) and personal interviews with students and lecturers.
3	Dinmore, S. P. (2014)	Australia	Article examining student-centred learning pedagogies and need for inclusive university curricula.	Argues the adoption of Universal Design for Learning (UDL) is the most appropriate solution, giving examples of UDL implementation.
4	Cole, A. W., Lennon, L., & Weber, N. L. (2021)	United States Undergraduate students enrolled in F2F courses and online courses	Enquiry into factors that predict student engagement in online courses and their sense of belonging to the university. Also queried is the influence of participant's year-level.	Statistical analyses of surveys undertaken by students enrolled in F2F and online courses (n=246) and exclusively online courses (n=71). Surveys queried online learning engagement, learning climate, and college experiences.
5	Aparecida do Nascimento dos Santos, D., Schlünzen, E. T. M., & Schlünzen, K., Jr. (2016)	Brazil Teacher training at 2 different universities	Article exploring incorporation of inclusive and special education in teacher training programs	Mixed method study using questionnaires, reflective pieces, discussion forums and portfolios.
6	Falloon, G. (2012)	New Zealand Post graduate education students	Investigation of student perspectives and the factors influencing them in virtual classrooms	Mixed method investigation into student perceptions using semi-structured interviews, anonymous surveys, and screen recordings of sessions (n=22).
7	Farooq, O., & Matteson, M. (2016)	United States Library and Information Science	An investigation into engagement of online library and information science students and the challenges and barriers they encountered	Qualitative case study using voluntary instructor and student reflections (n=9) after sessions.

No.	Literature	Context, Learning setting and Participants	Purpose	Design and Methods
8	Forbes, D. (2017)	New Zealand Student and graduate teachers	Case study of the professional use of social media across programs and cohorts.	Narrative review of journals and reflective work of students and graduates using social media
9	Graziano, K. J., & Bryans-Bongey, S. (2018)	United States Deans and associate deans of teacher training programs	Review teacher training programs to demand for online teaching.	Survey of academics (n=215) responsible for teacher training programs to assess teacher preparations in the creation and use of online materials.
10	Gupta, M. M., Jankie, S., Pancholi, S. S., Talukdar, D., Sahu, P. K., & Sa, B. (2020)	West Indies India Medical and allied health professional training	Review article concerned with the impacts of the COVID-19 pandemic on systems associated with the delivery of education and training of medical and allied health care professionals.	Narrative review of methods of assessment in health education and analysis of possible approaches suitable for use during COVID-19 pandemic.
11	*Hehir, E., Zeller, M., Luckhurst, J., & Chandler, T. (2021).	United Kingdom	Literature review of remote learning impact on student connectedness	Systematic literature review
12	Ibáñez-Carrasco, P., Worthington, C., Rourke, S., & Hastings, C. (2020)	Canada Researchers of HIV from various disciplines	Longitudinal case study of training program using blended learning methods.	Mixed methods approach including focus groups (n=13), thematic analyses of self-reports (n=65), and interviews (n=3) from 2009 to 2019.
13	Johnson, G. M. (2015)	Australia 1st year educational psychology students	Investigation into factors of physical and psychological well-being which predict university student satisfaction with e-learning.	Analysis of student demographics and their responses to satisfaction survey and a health survey of cohorts in blended classes (n=154) and fully online classes (n-23).
14	Johnson, N. List-Ivankovic, J., Eboh, W. O., Ireland, J., Adams, D., Mowatt, E., & Martindatle, S. (2010)	Scotland 2nd year nursing and midwifery students	Case study of module teaching research and evidence-based practice.	Description of past practice and current practice using blended learning approach.
15	Kandemir, B., & Kiliç Çakmak, E. (2021)	Turkey	Systematic literature review of describing distance education's structure	Content analysis and data visualization using MAXMAPs software.

No.	Literature	Context, Learning setting and Participants	Purpose	Design and Methods
16	Lin, Y., & Nguyen, H. (2021)	Australia International student	Reflections and self-observations of first author's experience undertaking synchronous and asynchronous e-learning	Autoethnography methodology
17	Mu, K., Coppard, B. M., Bracciano, A. G., & Bradberry, J. C. (2014)	United States Doctoral occupational therapy graduates	Study to evaluate graduate outcomes in a traditional and a hybrid entry level doctorate of occupational therapy (OTD) program.	Retrospective study comparing academic and clinical fieldwork performances of students undertaking traditional (n=81) versus hybrid/blended programs (n=13).
18	Nieuwoudt (2020)	Australia	Study exploring the relationship between students' synchronous and asynchronous online class attendances with academic success	Data analysis of number of hours, times in synchronous and asynchronous activities, discussion boards, and academic grades of students studying two subjects in 2018 (m=164)
19	O'Brien, M., & Freund, K. (2018)	Australia Undergraduate economic students at regional university	Report of lessons learnt using social media blogging to assist students in undertaking research in a blended learning situation.	Mixed methods using surveys and interviews of students (n=25), staff interviews (n=5) and review of literature.
20	Orange, A., Heinecke, W., Berger, E., Krousgrill, C., Mikic, B., & Quinn, D. (2012)	United States Sophomore engineering students Four universities	Investigation into the use and effectiveness of Web 2.0 tools in synchronous F2F engineering classes supplemented by asynchronous content and communication.	Mixed methods evaluation using student and professor surveys, students' usage statistics, course grades and blog posts.
21	Pearson, V., Lister, K., McPherson, E., Gallen, A., Davies, G., Colwell, C., Bradshaw, K., Braithwaite, N., & Collins, T. (2019)	United Kingdom Disabled students at 3 universities	Enquiry of staff to identify inclusive practices for disabled students and identify issues and difficulties.	Mixed methods approach including surveys of academics (n=72), student support staff (n=82), curriculum production and technical staff (n=57) and associate lecturers (n=56) for knowledge and awareness of inclusive practices and support services. Focus groups of disabled students and some staff.
22	Peterson, A. T., Beymer, P. N., & Putnam, R. T. (2018).	United States Undergraduate teacher education students	Examination of the effects of synchronous versus asynchronous interaction on students' sense of belonging in online,small-group, discussions	(n= 52)

No.	Literature	Context, Learning setting and Participants	Purpose	Design and Methods
23	Quevedo, A. (2011)	Brazil, Catholic University 3rd year student teachers	Exploratory quantitative and qualitative study on the experience and impacts of blended learning in student teacher program.	Mixed methods, longitudinal investigation (2008, 2009 and 2010) using survey responses (n=84) and analysis discussion forum responses of student teachers using blended learning.
24	Seikkula-Leino, J., Ruskovaara, E., Hannula, H., & Saarivirta, T. (2012)	Finland Teacher training curriculum	Examination of curricula for academic teacher education and vocational teacher education.	Qualitative analysis of the curricula of academic and vocational teacher education providers looking for evidence of entrepreneurship education.
25	Tripathi, R. K., Kurle, D. G., Jalgaonkar, S. V., Sarkate, P. V., & Rege, N. N. (2017)	India 2nd year medical students studying in pharmacology subject	Study investigating the timing of introducing e-learning on students' performances and their perceptions in pharmacology subject.	Quantitative statistical analysis of students' performances on 40 multiple choice questions testing syllabus, pre and post interventions for 3 cohorts within subject, where e-learning was pre-subject (n=168), post-subject (n=168) or replacement of subject (n=173). Additionally, students undertook 14 question survey on their perceptions.

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VIRTUAL TEAM BUILDING IN AN INTELLIGENT COLLABORATIVE LEARNING ENVIRONMENT

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ABSTRACT

Aim/Purpose	The main purpose is to study the experience of using virtual team building as a means of forming educational and research teams in the context of the development of online education and its effect among students and teachers of higher educational institutions.
Background	Methods ensuring effective engagement of students in learning are critical to the success of online education. The most obvious problems in higher educational institutions are procrastination, academic dishonesty due to easy access to electronic resources, decreased attendance, and insufficient interaction between teachers and students.
Methodology	The research methodology is based on an empirical approach, which is a research survey using a questionnaire to collect data based on closed-ended questions. For quantitative analysis, the independent sample t-test was used. The survey was conducted among students and teachers of two educational institutions in the Russian Federation.
Contribution	This study is of practical and scientific importance as it can contribute to the introduction of virtual team building in the modern education system.

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Findings	Based on the analysis of the data obtained, it can be concluded that students and teachers approximately equally assess the impact of team building on the ability to get to know each other better, improve communication skills, and psycho-emotional intimacy. Despite the need and sometimes no alternative to virtual team building (for example, during a pandemic), half of the sample of students (50.8%) agreed that team building was more effective in an offline environment while 64.3% of teachers believe that the effectiveness could have been higher in the offline environment. The respondents assessed the positive effect of team building on their interest and motivation to study or work.
Recommendations for Practitioners	These findings can contribute to a broader and faster implementation of virtual team-building practices in the education system of the Russian Federation and other countries of the world. The results of this study can be applied by higher educational institutions that are interested in increasing team cohesion, interest, and motivation to study or work, as well as the creation of closer and trusting relationships, and an atmosphere of psycho-emotional safety.
Recommendations for Researchers	This topic requires more observations to verify the influence of student personality on the effectiveness of virtual team building in intelligent collaborative learning environments.
Impact on Society	The study highlights the importance of communication between the student and the teacher, as well as between students, as psycho-emotional well-being in the micro-society results in a better academic performance.
Future Research	Further research can be aimed at studying the difference in the effectiveness of team building in online and offline learning environments, as well as the impact of team building on the teaching staff.
Keywords	collaborative learning, smart environment, virtual team building, virtual reality, online education

INTRODUCTION

The COVID-19 pandemic spread throughout the world, creating not only a unique challenge but also a potential opportunity for online education (Crawford et al., 2020; Mumford & Dikilitaş, 2020). Many online learning platforms, methods, as well as new approaches, are currently available for students who will undoubtedly benefit from the rapid acquisition of knowledge and information (Hwang & Chen, 2019; Lu et al., 2017; Vorona-Slivinskaya et al., 2020). However, many studies show that students use these electronic resources with limited assimilation and integration into their learning processes (Bozkurt & Sharma, 2020; Goksel & Bozkurt, 2019; Losh, 2014; Sana et al., 2013). Thus, methods ensuring effective engagement of students into learning are critical to the success of online education. The most obvious problems in higher educational institutions are procrastination, academic dishonesty due to easy access to electronic resources, decreased attendance, and insufficient interaction between teachers and students (Bell, 2018; Patrzek et al., 2015).

The most common understanding of team building involves the process of leading a group of people to work together more effectively as teams, especially through special activities and events held to increase motivation and support cooperation (Zhu & Wang, 2020). Virtual team building, for the purposes of this study, involves the above activities partly, predominantly, or exclusively, online thanks to electronic communication tools, social networks, and other Internet technologies (Saviom, 2021).

Virtual team building can be an important tool in a smart digital collaborative learning environment. This is a set of actions in learning environment among members of learning project or research group that build trust, develop participants, bring cohesion to the team, clarify team norms, promote understanding of the work of virtual colleagues. and conduct effective meetings in a virtual environment. To keep members engaged, leaders must regularly reassess the needs of their team and develop relevant team building activities (Gartner, 2021).

Team building encourages member involvement and helps newcomers to break down barriers while creating a relaxed atmosphere for socializing and communicating. In an educational context, these aspects of teamwork are especially important because they reduce anxiety, improve cognition, and promote academic achievement (Zhang et al., 2020). However, some team members in a team building exercise may think about negative aspects: time wasted, unwillingness to engage in activities of any kind, and consideration of team building as a burden (Hazley, 2019).

Digital transformation is not a new phenomenon, and it has been accompanying the activities of higher educational institutions for several years (Kopp et al., 2019; Leszczyński et al., 2018). The digital transformation of higher educational institutions is a pressing issue of education stakeholders. At the moment, there are opportunities for the application of IT technologies in all spheres of life, so universities must solve the problem of training potential professionals (Abad-Segura et al., 2020; Bond et al., 2018; Sandkuhl & Lehmann, 2017). Digital transformation in the context of higher education can be seen as the collection of all digital processes required for the transformation process implementation, which enables higher educational institutions to make optimal and positive use of digital technologies (Kopp et al., 2019).

With due regard to the Sustainable Development Goals (SDGs), especially the goal of ensuring inclusive and equitable quality education and the promotion of lifelong learning opportunities for all, and the goal of building resilient infrastructure for innovation, virtual team building is a progressive research area. Moreover, taking into account the prospects and difficulties that educational institutions face when introducing virtual team building into a digital collaborative learning environment, the research topic is relevant. In addition, this research is one of the few and reflective study of the effect of virtual team building on different aspects of student life in the context of a higher educational institution (Lapina & Prakasha, 2022; Sumtsova et al., 2018).

The most important problem for higher education institutions during virtual team building is the high complexity of the proposed team building software tools and the need for regular monitoring and mentoring of this process (Zhang et al., 2020; Zhu & Wang, 2020). The problem is even more difficult, especially in conditions of remote or online learning, as was the case under lockdown restrictions (Crawford et al., 2020; Hodges et al., 2020). The contribution of this study is to demonstrate the availability and ease of implementation of team building tools to support online learning in a university context. The methods proposed in this study include organizational tools and communicative game-based easy to implement in terms of involving computer applications, online learning methods or other elements of the digital environment. The proposed methods include minimal game-based team building techniques that allow to abandon the close teachers' and administrative control throughout the team building process.

This study is of practical and scientific importance as it can contribute to the introduction of virtual team building in the modern education system. Team building can be seen as a fun activity that can help students and teachers build their interpersonal connections and maintain social relationships, not only in the context of offline education but also in the course of a remote educational process when personal contact is not possible (Modolin & Grace, 2018).

Literature Review

In the practice of university education, approaches associated with practical training and training focused on solving real world problems are widespread (Yuberti et al., 2019). Many methods for implementing these approaches involve the use of simulations of real situations and problems in companies in which graduates will have to work. In this case, researchers point to the high efficiency of using game-oriented teaching methods (Jacobson et al., 2016; Maratou et al., 2016; Sandkuhl & Lehmann, 2017). The involvement of virtualization tools and the Internet makes it possible to make the gaming approach also virtualized.

Virtual immersive learning research is viewed as an innovative model for the study of important scientific knowledge and new practices for the implementation of educational processes. This approach involves the use of a playful virtual world to help learners experience virtual sensation modeling combined with the use of an agent-based computer model to perform computational research activities (Jacobson et al., 2016).

There is widespread research on role-playing games focused on software project management (SPM) in a 3D multiplayer virtual world, necessarily involving the construction of virtual teams by the players. Various platforms are used to create a virtual environment that facilitates collaboration and realistic student interaction. Through the simulation of a real company activity, the game approach aims to develop skills for real world problem solutions. It improves the experimental study of problems related to people, communication, and collaboration of members that are not easily taught with the help of standard teaching methods (Hodges et al., 2020). Students are assigned roles to overcome challenges initiated by non-game units (software-controlled units) and at the same time to collaborate with other students and the teacher.

The instructor, who plays the key role in the game, can monitor players, intervene, and dynamically change certain parameters of the game scenario while adapting it to the difficulties faced by the player (Maratou et al., 2016). It is important for teachers to overcome difficulties in mastering and implementing online methods and elements of the digital environment in educational activities (Hone & El Said, 2016; Kang & Zhang, 2020). The presence of these obstacles makes it important to study the opinion and assessment of teachers of the experience of virtual team building (Ghahramani et al., 2022; Sumtsova et al., 2018).

The issue of increasing student involvement and motivation is being given a lot of attention in educational practices (Azevedo, 2015; Christenson et al., 2012). Online collaborative learning and the creation of virtual learning communities is common practice (Dockerty, 2019). The Internet helps to reshape formal and informal education in the digital age, giving instruments for virtual learning and research team formation (Harasim, 2017).

Online learning, including e-learning and massive open online courses, is widely studied in the field of education or information technology. Available research provides evidence to explain the results or effectiveness of online learning (Burden et al., 2016; H. M. Dai et al., 2020; Hone & El Said, 2016). However, most of them do not consider the difficulties that students experience when they join online courses. In particular, students may feel more anxious and burdened as the intervention involves active involvement, personal interest, and dedication.

Team building, and the use of teamwork rather than just peer interrelations, is becoming increasingly important in the context of pragmatically problem-solving real-life learning (Popta et al., 2017; Yuberti et al., 2019). Within the framework of project-based and practice-oriented learning, classmates and students of the same discipline form project teams and research groups, united by a common internal regulation, common goals, and distribution of functions and tasks within the project. This approach to learning enhances the skills of both future employees and future scientists (Zhu & Wang, 2020). Innovation management and company intellectual property management processes also include the adequate functioning of teams as a mandatory aspect and it should be mastered by future employees while still studying at the university (Voskresenskaya et al., 2020).

Team building plays an important role in creating a positive learning environment and has many benefits ranging from being inspired by learning to understanding the strengths and weaknesses of each participant so that everyone can be understood and supported. A significant bonus of team building can be an increase in mutual respect, elimination of conflicts between group members, and the creation of more trusting relationships (Y. Dai et al., 2019). Team building activities can be used to improve communication and time management, as well as strengthen connections between the members when they compete with each other or collaborate to defeat opposing teams (Hazley, 2019).

In the field of virtual team building, events help employees quickly adapt to the new teleworking lifestyle. In the field of pedagogy, students are facilitating their process of collaborating on learning and research projects in teams through virtual team building in an era of gradual dominance of online learning. This can help minimize negative impacts of online culture in the workplace, such as the inability to separate work from home, loneliness, and added stress (Saviom, 2021). A study that found that virtual team-building exercises increased employee productivity and decreased absenteeism, and they improved profitability by 41% and 21% respectively (Hickman & Robison, 2020).

Modern team building offers ample opportunities for the development of technology programs using unusual gadgets while taking team building away from purely physical or intellectual tasks to a purely digital approach. The use of a game approach in teaching and the formation of communication and group skills, which include team building, encourages the development of a variety of skills, including strategic thinking, time management, and innovation. However, the participants may perceive it as entertainment immersing themselves in the fun process of solving puzzles rather than as another exercise. Team building in virtual reality makes it possible to place the team into a digital world that is not subject to the laws of the real world. In VR games, players can easily fly, climb a mountain, and even be transported into the future – the potential has no boundaries (Hazley, 2019).

Team building in the context of university education can lead to the creation of closer business and educational ties of graduates with the university and contribute to their further successful interaction in university teaching and research projects. The specific psychological bonds formed by team experiences differ from those of peers and cannot be formed in the course of generally accepted practices of students' classes (EFSOL, 2018).

The issues of increasing student motivation and collaboration are widely discussed (Lee et al., 2019; Park & Kim, 2022; Visser et al., 2019). The proposed approaches and tools are effective but are more focused on improving the process of mastering knowledge and cooperation in the learning process. At the same time, several skills required in teamwork when dividing the functions and areas of activity of participants cannot be obtained, and the process of virtual team building can be a solution to this problem (Y. Dai et al., 2019). The experience of using team building in business is little used in the university environment, despite the great potential for preparing future graduates for work in companies (Ghahramani et al., 2022). This study is intended to partly close this gap.

Setting Objectives

The motive for conducting the study is the need to obtain subjective assessment data on the impact of virtual team building in an intelligent collaborative learning environment in the context of higher educational institutions. The research question can be formulated as follows:

> *Is it possible to significantly improve the subjective assessment and effect of team building in a student and at the same time teaching audience using the easy game-based tools for providing a team building experience?*

It is necessary to find out whether virtual team building can develop mutual respect in the micro-society, raise morale, eliminate internal conflicts, and help to stay in touch with colleagues, and encourage them to work closely together. It can increase the efficiency of collaboration and allow people to interact, as well as exchange and receive constructive feedback. Thus, when the participants look at the problem through the prism of innovation, they become more involved in the achievement of long-term goals. A common goal motivates people to work hard to achieve it, which in turn leads to a higher productivity index with no burnout. Also, virtual team building exercises can help build meaningful relationships and connections between geographically dispersed team members.

The main purpose of the research is to study the experience of using virtual team building and its effect among students and teachers of higher educational institutions. The study attempts to prove that the introduction of virtual team building activities makes the learning process more effective which, in addition to being informative, also has emotional significance for students and teachers to create the feeling of a real 'team'.

The research objectives are as follows:

1) To investigate the impact of the easy implemented game-based virtual team building tools on improvement of the evaluation of the team building experience in a digital collaborative learning environment on the Zoom platform.
2) To identify the effectiveness and degree of satisfaction from the implementation of virtual team building by conducting a survey among students and teachers of higher educational institutions.
3) To carry out a comparative analysis of the results of a teacher survey and a student survey in order to identify which of these groups received more benefits from the implementation of virtual team building activities.

The team building mechanism at universities in Russia and many developing countries, as far as it is possible to assess, is either not used, or only its limited elements are used; for example, some types of team building games described above (Lapina & Prakasha, 2022; Sumtsova et al., 2018). An obstacle to the implementation of this method is ignorance about it, doubts about the need for its implementation, uncertainty about its effectiveness and the goals it achieves (Ghahramani et al., 2022; Yuberti et al., 2019). Another barrier is the difficulty in implementing online project team building and team building tools (Modolin & Grace, 2018). The results presented in the proposed study allow us to evaluate the experience gained by students and teachers and present their subjective assessment of changes as a result of the implementation of virtual team building. Real and simple team building tools are also presented, the implementation of which is maximally simplified and accessible to universities. The presented experience and assessment should help other universities to quickly decide on the implementation of this method to deepen the integration of student learning with real business practices and business processes after graduation and contribute to a wider implementation of this method in many universities in Russia and other countries.

METHODS AND MATERIALS

RESEARCH DESIGN

The research methodology is based on the research survey using a questionnaire to collect data based on closed-ended questions. The survey is aimed at obtaining a subjective assessment of various aspects of team building in the context of online learning at the university by students and teachers. The assessment obtained will allow us to refine and improve the applied methods of team building and make it more attractive for participants and effective for preparing for the future work of university graduates. The survey was conducted among students and teachers after a certain time allotted for using the Zoom application as a virtual team building tool in accordance with the tasks, team building games, and initiatives described later in this section.

In 2020, Zoom has become one of the leading video conferencing applications. Zoom allows users to virtually interact with their colleagues when face-to-face meetings are not possible, and it has also proven to be effective in the context of public events (Tillman, 2021). The Zoom platform was chosen due to its maximum prevalence and use in most educational institutions around the world and free of charge. Since the goal of this study is to implement the easiest and most accessible team building tools for implementation, this platform seems to be the most appropriate.

Zoom is a cloud-based service that can be used for virtual meetings with other people either through video/audio conferencing or both; users can chat in real time and record sessions to be viewed later. This software is compatible with Windows and macOS and can be found on Android and iOS platforms. Zoom allows users to join meetings and share their screens. Conference participants can also tune their microphones, start or stop video stream, change account names, as well as invite other participants to a meeting (Tillman, 2021).

Team building methods for this study were taken from the studies reviewed in the literature review, as well as from sources provided in the references in the description of individual exercises. The main tasks of team building are based on the views common to many researchers (Ghahramani et al., 2022; Hazley, 2019; Modolin & Grace, 2018).

The student participants of the study were divided into project groups in accordance with the course in which they studied and within their own study group or together with students from several groups studying the same topic. The teachers accompanied this learning project process by guiding and supporting the participants in each individual project group. Each project group was considered within the framework of the study as a team for which team building classes were held. The team building sessions were separate from the training and project sessions and were devoted exclusively to the team building processes and related discussions on the work on the project, identifying leaders, distribution of responsibilities and administrative issues, as well as personal communication between the participants of each of the teams.

The researchers deliberately did not specialize or differentiate in any way the teams that worked on educational projects in various professions and disciplines in order to evaluate only those aspects that relate to team building, and not individual academic disciplines.

The important team building tasks were the tasks on which the work of the participants, both teachers and students, was concentrated during the team building meetings. The important team building tasks were as follows:

1) To find leaders to organize the process and make the participants take part in the general meeting of the team. The teachers in each of their groups and students selected by the students who they consider suitable participants became these leaders.
2) The meetings were held as weekly 80-minute videoconferences divided into two Zoom sessions for 18 weeks. The time of the lesson was determined by the teachers and agreed with the students independently. It is important to note that the group consisted of 8-10 people so that each participant had time to speak.
3) To determine a clear action plan at each meeting. The leaders found in the team in accordance with the 1st task in this list were clearly informed about the objectives of presented here research and each of them was given a plan of team building activities, described below. It included 9 activities, and each activity was performed twice.

The nine virtual team building games and initiatives included (Scavify, 2021):

1) Virtual team meetings
2) Shared virtual workspace
3) Peek into each other's homes
4) Desert island scenario
5) Discussion of global issues
6) Movie night
7) Casual conversation channel
8) Personal facts and guessing
9) Photo sharing.

Participants

The survey was conducted among the 372 students and 42 teachers of two educational institutions of the Russian Federation: Kuban State Agrarian University and Kuban State Technological University. The universities were chosen randomly, but in the same region, in order to expand the sample and for the convenience of the study. Participants among students were selected on the basis of a random sample; teachers were also selected on a random basis but limited by the fact that these teachers should currently teach those students who were already selected for participation in the study. Since the approach assumes the widest possible context and the use of team building for any specialties and any educational context, no additional selection filters were introduced. All participants gave consent to participate in the study. The team building practice lasted from March to July 2021. These practices included not only team meetings, but also specialized team building games and team building tasks as described above. This study involved students and teachers of higher educational institutions who took part in Zoom conferences with the introduction of team-building games.

The influence of gender and age characteristics was not investigated in the study and the participants were not asked to indicate their gender in the questionnaire. As a result, 372 students and 42 teachers were interviewed (a total of 414 people). More detailed information regarding the number of participants from each institution is given in Table 1.

Table 1. Data on the number of participants from each educational institution

Educational institution	Students	Teachers
Kuban State Agrarian University	183	19
Kuban State Technological University	189	23
Total people	372	42
Total %	89.8	10.2

Research Instruments

With the help of the Survio database, an online questionnaire (Appendix) was sent to the participants via email; the email addresses were provided by the administration of the educational institutions. The database provided access to filling out the questionnaire to each participant using the access keys sent to them and helped to store and manage the received completed questionnaires during their processing. This also ensured the uniqueness of each questionnaire and the preservation of the anonymity of the participants. Those willing to participate anonymously filled in an online form, which guaranteed their data confidentiality. The respondents who took part in the survey were automatically considered to be the research participants. All questionnaires were filled out correctly and found suitable for further statistical processing.

The respondents were asked to indicate how much they agree with the statements on a 4-point Likert scale, where:

1 - Strongly agree (SA)
2 - Agree (A)
3 - Disagree (D)
4 - Strongly disagree (SD) (Appendix)

The questionnaire contains 13 questions. The first three questions define the respondent's profile: age, status, university. Next, there is a list of 10 statements aimed at assessing the effectiveness of virtual team building.

The questionnaire was created by the author based on the experience of team building research and the content of the surveys described in the research literature mentioned in this article. Internal consistency and reliability were tested using the Cronbach Alpha method. To do this, the responses were encoded with numbers, as indicated above. The result obtained is a = 0.701, which suggests that the reliability of the questionnaire is high enough for its use. Validity was checked by a survey of experts. Fifteen teachers from both universities were invited, whose students took part in the survey, 8 and 7 teachers, respectively, who did not take part in the survey. All of them have at least 2 publications in peer-reviewed journals on the topic of team building and have been dealing with problems of university pedagogy in various fields for at least 5 years, as well as teaching students for at least 7 years each. They were asked to assess the compliance of the questionnaire with the scope and objectives of the study on a 5-point Likert scale, where 1 point is "almost does not correspond" and 5 points is "completely corresponds". A mean score of 4.27 was obtained (SD = 0.31). Thus, it can be assumed that the questionnaire has sufficient validity for the purposes of the study.

Data Analysis

Descriptive statistics are used to analyze the results obtained according to the percentage of responses. For quantitative analysis, the independent sample t-test was used. The data on the frequency, mean, and standard deviation were used to describe the statistics to determine the degree of influence with the use of the t-test. The t-test was used to compare the mean by identifying significant differences at the 0.05 level. The mean values obtained in response to each of the questions separately for teachers and for students were compared with other questions to determine the presence of statistically significant differences. Thus, the validity and internal relativity of the proposed questionnaire were tested. In fact, the hypothesis was tested that there are no statistically significant differences in the respondents' answers to the questions, which can be interpreted as the fact that the corresponding questions do not contain significant valid and independent values (variables) to be measured. In relation to all mutual pairs, the question received a value of $p \leq 0.05$ (Table 2, Note). Accordingly, as a result of the study, this hypothesis was rejected in relation to all questions of the questionnaire. Corresponding tabular data is omitted to save space. The data obtained were analyzed in SPSS Statistic.

Research Limitations

This study has certain limitations. The research sample included students and teachers from only two universities. Data representing the entire student and academic population of the country were not collected, which may not accurately reflect the effectiveness of virtual team building. Further research should focus on educational institutions across the country for a more reliable generalization of results. Moreover, research can be conducted not only among students, but also among teachers to improve their teamwork.

Also, the limiting factor is the curators of the study (teachers), who were different in each student group, which could indirectly have an effect on the final result. However, within the framework of the research design, it would not have been possible to avoid this. In addition, this can be offset by the fact that there was one program of team building games for all participants.

It is worth noting that tendencies towards independence or extroversion can influence student perception of team building assignments. Introverts may be less active as they have difficulty in social interactions, including virtual ones. More research is needed to verify the influence of student personality on the effectiveness of virtual team building in intelligent collaborative learning environments.

RESULTS

The results of the survey regarding the impressions of students and teachers and the subsequent effectiveness of the implementation of the virtual team building program are presented in Table 2. The survey results show that both students and teachers were satisfied with their participation in team building activities (Statement No. 1). Thus, the total percentage of SA and A options is 84% and 73.8% among the students and the teachers, respectively Also, 89.8% of teachers and 88.1% of students reported that participation in videoconferences helped them get to know each other better (Statement No. 2). These values show that the closer acquaintance effect obtained in the course of team-building activities is significant for both students and teachers.

The results of Statement No. 3 show that 73.4% of students and 81.0% of teachers believe that the group has become more cohesive. In this case, there is a slight prevalence of teachers, which can be explained by the subjective perception of the group leader while the group itself is less homogeneous and has more complex and broader social interactions.

It should be noted that 90.9% of students and 88.1% of teachers believe that virtual team building has a positive impact on their team (Statement No. 4). At the same time, 89.2% of students and 88.1% of teachers think that team building is a good way to improve communication skills and the psycho-emotional atmosphere in the team (Statement No. 5).

It was interesting to find out whether the respondents thought that team building was just a waste of time, especially the teachers, who were required not only to participate but also to lead all the processes, which increased their workload (Statement No. 6). Thus, 74.7% of students and 64.3% of teachers appreciated the time they spent on virtual team building activities. Among the teachers, the percentage is lower, which may be due to their extracurricular activity.

Table 2. Results of the survey on the effectiveness of the implementation of virtual team building*

Question	Students			Teachers		
	Option	**Frequency**	**Percentage**	**Option**	**Frequency**	**Percentage**
1. Generally, I was pleased with the participation in team building activities.	SA	101	27.2	SA	9	21.4
	A	198	53.2	A	22	52.4
	D	54	14.5	D	8	19.0
	SD	19	5.1	SD	3	7.1
2. Participation in video conferences with my classmates and teacher (students) helped me get to know them better.	SA	150	40.3	SA	8	19.0
	A	184	49.5	A	29	69.0
	D	28	7.5	D	4	9.5
	SD	10	2.7	SD	1	2.4
3. Team building has made my group more cohesive.	SA	104	28.0	SA	10	23.8
	A	169	45.4	A	24	57.1
	D	68	18.3	D	5	11.9
	SD	31	8.3	SD	3	7.1
	SA	142	38.2	SA	10	23.8
	A	196	52.7	A	27	64.3

Question	Students			Teachers		
	Option	Frequency	Percentage	Option	Frequency	Percentage
4. I think virtual team building has had a positive impact on my team.	D	22	5.9	D	5	11.9
	SD	12	3.2	SD	0	0.0
5. Team building is a good way to improve communication skills and the psycho-emotional atmosphere in the team.	SA	143	38.4	SA	18	42.9
	A	189	50.8	A	19	45.2
	D	29	7.8	D	3	7.1
	SD	11	3.0	SD	2	4.8
6. I believe that team building was not just a waste of time.	SA	120	32.3	SA	8	19.0
	A	158	42.5	A	19	45.2
	D	74	19.9	D	12	28.6
	SD	20	5.4	SD	3	7.1
7. It seems to me that team building would have been more effective in an offline environment than in a virtual one.	SA	52	14.0	SA	5	11.9
	A	137	36.8	A	10	23.8
	D	115	30.9	D	18	42.9
	SD	68	18.3	SD	9	21.4
8. Team building helped me build relationships with some people (students) from my group.	SA	54	14.5	SA	5	11.9
	A	103	27.7	A	10	23.8
	D	140	37.6	D	17	40.5
	SD	75	20.2	SD	10	23.8
9. Team building has developed my deep attachment to my educational institution.	SA	132	35.5	SA	6	14.3
	A	189	50.8	A	21	50.0
	D	31	8.3	D	10	23.8
	SD	20	5.4	SD	5	11.9
10. Team building has had a positive effect on my interest and motivation to study/work.	SA	154	41.4	SA	10	23.8
	A	167	44.9	A	20	47.6
	D	33	8.9	D	8	19.0
	SD	18	4.8	SD	4	9.5

Note: SA - strongly agree; A - agree; D - disagree; SD - strongly disagree; $p < 0.05$

It was extremely important to find out whether the respondents think that team building would have been more effective in an offline environment than in a virtual one as there is personal contact with people (Statement No. 7). Thus, 50.8% of students believe that the effectiveness of team building in an offline environment would not have increased in contrast to 49.2% of learners who do not share this point of view. As for teachers, only 35.7% believe that team building in a virtual environment is more beneficial than in the real one. These results can be explained by the fact that students are younger than teachers and, therefore, virtual reality is perceived by them much more easily and is considered more acceptable.

It can also be noted that 42.2% of students and 35.7% of teachers managed to establish relationships with the help of team building activities (Statement No. 8). These indicators are not high, but it should be kept in mind that the majority of respondents probably did not initially have problem relationships with other team members.

The analysis of the manifestation of the attachment to the educational institution, which was observed in the course of team building activities, showed that 86.3% of students and 64.3% of teachers experienced this feeling (Statement No. 9). The indicator is higher among students, which can be explained by the subjective perception of student life at a young age.

Thus, the respondents noted a positive effect of team building on their interest and motivation to study and work: 86.3% of students and 71.4% of teachers agreed with the statement, which are also significant indicators.

To visualize the items under study, the data can be described in the form of a graph according to the criteria that relate to the positive effect of the introduction of team building activities (Figure 1).

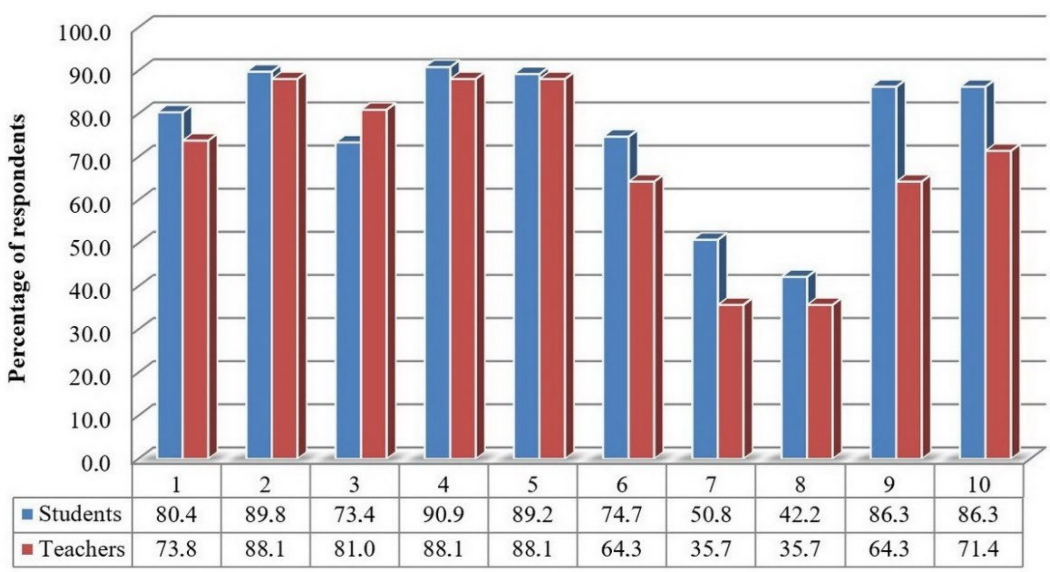

Figure 1. SA and A responses sum (from Table 2) reflecting the subjective assessment of the effect of introduction of team building

Based on the analysis of the data obtained, it can be concluded that students and teachers approximately equally assess the impact of team building on the ability to get to know each other better, improve communication skills, and psycho-emotional intimacy (Statements Nos. 2, 4, 5). The fact that team building has increased the cohesion of the team was noted by a slightly larger number of teachers compared to students (Statement No. 3). The majority of the students and the teachers do not consider team building a waste of time, even though there were not many teachers who agreed with Statement No. 6. An approximately equal percentage of students and teachers managed to improve their relationships in the team, although 57.8% of students and 64.3% of teachers disagreed with Statement No. 8; this indicates that there is no effect of team building activities on conflict resolution or processes associated with building relationships. Team building also contributed to the deeper attachment of students to the educational institution (Statement No. 9). This also applies to the assessment of the positive effect of team building on motivation and interest in learning; this indicator is higher by 14.9% among students compared to teachers.

DISCUSSION

The study highlights the importance of communication between the student and the teacher, as well as between students as psycho-emotional well-being in the micro-society results in better academic performance. A study by American researchers based on a two-year ethnographic analysis of global virtual teams (GVT) and involving six universities around the world (USA, China, South Korea, Germany, Israel, and India) demonstrated the fact that in a virtual environment, students are more actively involved in the learning process, can solve unforeseen problems and establish new ways of being, acting and thinking. This study highlights the dynamic nature of the team-building process design and provides important insights into how students can benefit from the implementation of programs based on virtual reality (Y. Dai et al., 2019).

Team building is a normative activity for most businesses, but it is practically not used in universities that train staff for business (Ghahramani et al., 2022). Team building tools can have an effect that significantly complements the project-based learning already implemented by many universities, learning based on solving real problems, and so forth (Lapina & Prakasha, 2022; Yuberti et al., 2019). The results of our study indicate a high appreciation by students and teachers of the results of this approach to learning, which can be relied upon to build the ability to work in a team after graduation in a new digital environment (Hazley, 2019; Lee et al., 2019).

Another study showed that, compared to traditional classroom learning, online learning on forums effectively increased student engagement and motivation, as well as reduced procrastination and plagiarism. Thus, online practices can be seen as a useful complementary approach to traditional classroom learning (Kang & Zhang, 2020). Supported by the survey data presented here, increased motivation and involvement in the online research and learning process can be enhanced by the team building process and stimulate online learning.

Australian researchers also described the results of a two-week intervention involving the use of a CSI approach in two groups, which demonstrated a considerable increase in student success (Jacobson et al., 2016). This overlaps with the findings obtained in the present paper. Thus, it can be stated that virtual team building has shown positive effects on student motivation and interest in learning (Modolin & Grace, 2018; Park & Kim, 2022).

An effective learning process can keep students engaged (Pehmer et al., 2015). Other studies have shown that an intelligent and adaptive learning platform combined with a well-designed team can deliver good results and that digital processes in higher education can increase student engagement in learning within the framework of a wide range of activities and contexts (Zhu & Wang, 2020). It is possible that the simpler and less technologically demanding team building tools are used in online interaction, the more stable results can be obtained, as indicated by the subjective assessments of students in our study (Maratou et al., 2016; Mumford & Dikilitaş, 2020).

Personalized instructional interventions such as team building can effectively improve student behavior, attitudes, motivation, and academic performance in a blended learning environment (Branch & Dousay, 2015; Zhang et al., 2020). Online peer and teacher feedback has potential benefits for student learning in terms of better relationships and an atmosphere of psycho-emotional safety (Popta et al., 2017). Some researchers argue that peer feedback may play a more important role in online learning compared to traditional learning (Ramdani & Widodo, 2019). The subjective assessment of teachers and students equally in our study confirms the improvement in the emotional climate and well-being in the team. In this case, the team, as a new organizational structure, looks more prosperous from the point of view of its members than a regular study group, which is also confirmed by some researchers (Popta et al., 2017; Sumtsova et al., 2018).

CONCLUSIONS

Based on the results of the survey regarding the experience of students and teachers and the subsequent effectiveness of the implementation of the virtual team-building program, it can be concluded that both students and teachers were satisfied with their participation in team-building activities (84% and 73.8% among the students and the teachers, respectively). It was found that 89.8% of teachers and 88.1% of students reported that participation in videoconferences helped them get to know each other better. The statement that team building has made the group more cohesive was confirmed by 73.4% of students and 81.0% of teachers. It should be noted that 90.9% of students and 88.1% of teachers believe that virtual team building had a positive impact on their team and 89.2% of students and 88.1% of teachers think that team building is a good way to improve communication skills and the psycho-emotional atmosphere in the team. Team building tools received a high subjective assessment of students and teachers and demonstrate their readiness for this form of activity in addition to the main training. This opens up opportunities to prepare students for teamwork in business after graduation.

Also, 74.7% of students and 64.3% of teachers appreciated the time they spent on virtual team building activities. In addition, 50.8% of students believed that the effectiveness of team building in an offline environment would not have increased in contrast to 49.2% of learners who did not share this point of view. As for teachers, only 35.7% believed that team building in a virtual environment is more beneficial than in the real one. It is the virtual team building experience that can enhance and support the experience of online learning and the use of a digital environment for learning and work.

It can also be noted that 42.2% of students and 35.7% of teachers managed to establish relationships with the help of team building activities. The analysis of the manifestation of the attachment to the educational institution, which was observed in the course of team building activities, showed that 86.3% of students and 64.3% of teachers experienced this feeling. In fact, the respondents noted a positive effect of team building on their interest and motivation to study and work: 86.3% of students and 71.4% of teachers agreed with the statement; the indicator of students exceeds that of teachers by 14.9%. Accordingly, team building can be isolated from other goals of its implementation only to improve the emotional state of teams and relations between students and teachers.

This study is of practical value as it demonstrates the positive impact of virtual team building in the university educational context. This fact can contribute to a broader and faster implementation of virtual team-building practices with simple instruments in the education system of the Russian Federation and other countries of the world. The results of this study can be applied specifically for implementation easy game-based team building meetings by higher educational institutions that are interested in increasing team cohesion, interest and motivation to study or work, as well as the creation of closer and trusting relationships and an atmosphere of psycho-emotional safety. In addition, the data obtained in the study can be used by researchers conducting studies on related topics.

Further research can be aimed at studying the difference in the effectiveness of team building in online and offline learning environments, as well as the impact of team building on the teaching staff as university teachers also need the positive effects of team building, which in turn can contribute to the effectiveness of their teaching practices. In addition, further research requires more observations to verify the influence of student personality on the effectiveness of virtual team building in intelligent collaborative learning environments.

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Appendix

Questionnaire

Personal information of the participant

1. Which university do you work/study at?

    ○ Kuban State Agrarian University

    ○ Kuban State Technological University

2. How old are you? ○ under 18 ○ over 18
3. What is your status in the educational institution? ○ student ○ teacher

Please agree/disagree with the statements on a four-point scale:

1 - Strongly agree (SA)

2 - Agree (A)

3 - Disagree (D)

4 - Strongly disagree (SD)

1. Generally, I was pleased with the participation in team building activities.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

2. Participation in video conferences with my classmates and teacher (students) helped me get to know them better.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

3. Team building has made my group more cohesive.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

4. I think virtual team building has had a positive impact on my team.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

5. Team building is a good way to improve communication skills and the psycho-emotional atmosphere in the team.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

6. I believe that team building was not just a waste of time.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

7. It seems to me that team building would have been more effective in an offline environment than in a virtual one.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

8. Team building helped me build relationships with some people (students) from my group.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

9. Team building has developed my deep attachment to my educational institution.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

10. Team building has had a positive effect on my interest and motivation to study/work.

    ○ *1. Strongly agree* ○ *2. Agree* ○ *3. Disagree* ○ *4. Strongly disagree*

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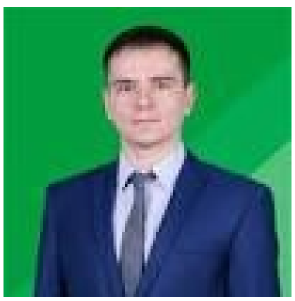

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GAMIFICATION SUPPORTING SMALL BUSINESS OWNERS' WORK-BASED LEARNING

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ABSTRACT

Aim/Purpose	This study attempts to apply gamification to support the training of small business owners in business web development from a work-based learning perspective.
Background	Web design describes the process of creating a website and embodies many different aspects, such as webpage layout, content production, and graphic design. However, there are many obstacles that small business owners face when developing their websites, such as time and budget constraints, lacking technical skills, and difficulties with content creation.
Methodology	Based on the literature review, a gamified training program was developed for website development. The new website design and development training method was compared with the traditional lecture training method from small business owners' perspectives in the specific work-based learning context.
Contribution	This study contributes to the field of work-based learning by developing an innovative gamified training program for small business owners in website development learning.
Findings	The results confirm that the gamified training program improved learning outcomes and satisfaction. The results of this study help advance the understanding of work-based training program design and provide insights to support small business owners in learning new technologies.
Recommendations for Practitioners	Results confirm that this new training system is superior to the traditional lecture training method. While much attention has been directed to website design and development learning or business activities of small business owners, this study emphasizes the need for work-based learning in such a context.
Recommendations for Researchers	This study also shows a potential way for future research by combining technology education and small business owners' needs.

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Impact on Society	The results of this study show the advantages of gamified training programs. For their future training program selections, small business owners should pay more attention to gamified training and education systems in the market. Furthermore, gamified training and education systems not only help small businesses but also could be adopted by mid-size or even large companies in their training programs.
Future Research	Future research should be conducted to investigate to what extent gamification improves work-based learning and how to design gamification to improve work-based learning.
Keywords	work-based learning, small business, gamification, training and education

INTRODUCTION

Small businesses are an important component of the modern economy and play a vital role in people's daily life (Tobing et al., 2019). Small business growth and entrepreneurship have been the foundation of the liberalization process in the world economy (Kozan et al., 2012). Business owners have many characteristics, such as being risk-takers and exhibiting openness to change. These characteristics result in small business growth, success, and failure. A small business owner can be defined as the owner of a privately-owned corporation with few employees and relatively less revenue than other regular-sized businesses. To make their business successful, small business owners make a variety of personal, financial, and relational sacrifices. For example, when business owners and entrepreneurs are considering business growth, oftentimes, they have to work extended hours and give up a lot of free time. In summary, business owners sacrifice their financial assets/properties and personal resources such as time and knowledge (Kozan et al., 2012).

Due to different reasons and various barriers, small businesses have been lagging behind and are slow to adopt e-commerce applications (Changchit & Klaus, 2020). One of the main dilemmas business owners face is time and budget constraints. Although small business owners may want to produce a successful website, the budget and time constraints may make it infeasible. Even if they may have a budget for website development, outsourcing the project to an IT company could be time-consuming (King, 2018). This development time includes the time for the technical website development and the communications between the small business owners and the outside developers regarding the actual needs of these small businesses. In many cases, the results are not fully satisfied (Blanks & Jesson, 2017). Lastly, in order to respond swiftly to market changes, small business owners desire to adapt to such changes through their websites (Nelson & Gibb, 1996). Unfortunately, outsourcing regular website updates to a third party is not a practical solution. It is in the best interest of small business owners to learn how to design and develop their business websites to facilitate their collaborations with IT professionals and leverage their efforts on web development. Good collaborations will, in turn, lead to savings, fulfillment of their needs, and market gains. Learning does not have to be a knowledge absorption process in s structured and formal format (Yeo, 2008). Work-based learning (WBL), one of the best learning methods centered around reflection on work practices (Hamilton, 2019), could be an optimal solution for small business owners to effectively learn the necessary skills and knowledge (Down, 1999). We have developed a study to educate small business owners on website development with practical resources and reasonable costs. In this study, we compared in-class lecture training, one of the traditional teaching methods, with a gamification method as a tool for engagement to help business owners develop effective websites by themselves. To the knowledge of the authors, this is the first academic research using a gamified training method in small business owners' website development education.

The rest of this paper is organized as follows: 1) The literature review section provides an overview of prior research in gamification, learning, and work-based learning. 2) The research method section elaborates the gamification and research design. 3) The results and discussions section summarizes and presents the findings. 4) The conclusions section presents the main contributions of this work.

LITERATURE REVIEW

GAMIFICATION

Gamification is a term that is currently gaining popularity and drawing the attention of business professionals in the current technology-driven world. According to Swacha (2018), gamification describes the use of game design in non-game settings to engage the target audience. It describes the process of taking something that already exists, such as a website, and incorporating game elements to increase users' efficiency and effectiveness in completing specific tasks (Legaki et al., 2020). Gamification generates fun from the games, results in learning from game-designed tasks, and eventually improves the user's engagement, motivation, and performance (García et al., 2017).

Gamified tasks typically help users in the following aspects:

- provides individuals with flexibility and freedom if they have preferences in completing tasks;
- teaches progression through a series of pre-designed activities. Gamification tasks are often designed and organized as a sequence of activities with increasing levels of difficulties and cognitive workload;
- sometimes instills socialization through collaboration

From a business perspective, gamification is positively altering business models by creating new ways to develop longer-term engagement, lead to user trustworthiness, and allow businesses to create and increase loyalty (Legaki et al., 2020).

Gaming developers are experts at finding techniques that attract the audience in order to keep them engaged. Gamification has seen rapid adoption in business, management, marketing, and ecological initiatives (Dicheva et al., 2015). After realizing the effectiveness of gamification, educators have decided to implement it in the classroom setting. Currently, gamification teaching strategies are being utilized to engage students' learning. According to Alhammad and Moreno (2018), gamification has been considered one of the key emergents and extensively adopted teaching technologies in current education. This is mainly because learning is like a game and contains rules, levels, and even rewards (Zarzycka-Piskorz, 2016). Therefore, students need to obey the rules in order to move up to the next level, and in the end, there is most likely a reward (good grades or teachers' nice comments). Thus, with the integration of game-like components into the classroom, students will engage by unlocking the next level of their assignment or challenging other students (Bai et al., 2020). In order to make teaching more like a game and engage students, educators can incorporate user levels, create challenges, give a second chance, allow students to make choices, and give rewards and badges. In academia, gamification is based on the idea that it supports and motivates students and, as a result, can enhance learning outcomes (Sanchez et al., 2020).

Gamification in business applications falls into two main categories: improvement of loyalty solutions and employee engagement support (Dale, 2014). Businesses adopted gamification applications and programs to achieve the following benefits (Vinichenko et al., 2016):

- Increase in labor productivity
- Create motivation
- Improve change management
- Align employees' expectations and goals with the organizational vision

During the last two decades, many large organizations implemented gamification applications and programs, such as Goobles at Google, carpool game at SAP, and Kuds from IBM (Dale, 2014;

Grams, 2017). Recently, Micro, Small, and Medium Enterprises (MSMEs) are starting to seek solutions in gamification. One study (Saputra & Rahmatia, 2021) found that 83% of MSMEs in Indonesia adopted gamification to foster their employees' motivation. Gamification is becoming an efficient method/mechanism supporting organizations to immerse their workforce more deeply in business processes and tasks (Cardador et al., 2017).

LEARNING

Professional skills and knowledge are fundamental to successfully supporting employees in running business processes (Fang, 2012). Knowledge is more abstract means acquired from questioning, discussing, and problem-solving, whereas skills can be defined as the capacity to apply the knowledge and the cumulated experience gained through completing certain activities (Cormier & Hagman, 1987). Skills, which lead to an observable outcome, could be an initial format of knowledge, which can be summarized as an abstraction from behavior (Jessup, 1991). Learning is a cognitive process of understanding and bringing knowledge and skills together to interact with the learning process (Bransford et al., 1989).

According to the Kolb learning cycle theory (Kolb & Fry, 1975), there are four stages of the learning cycle:

- Concrete Experience (CE): learners gain initial experience by doing something;
- Reflective Observation (RO): learners review and reflect on the experience;
- Abstract Conceptualisation (AC): learners conclude and learn from the experience;
- Active Experimentation (AE): learners plan and try out what they have learned.

To ensure effective learning, learners must complete all four stages of the learning cycle (Fergusson et al., 2018). Furthermore, this theory emphasizes the centrality of the learner in any learning process (Down, 1999). Traditional learning encourages passive learning, factural, and abstract thinking whereas the needs of small business emphasizes more on active learning (Saepudin et al., 2020). This learning difference in small business enhances the importance of non-formal education in business training and education, such as work-based learning (Corrales-Herrero & Rodríguez-Prado, 2018).

WORK-BASED LEARNING

Work-based learning is a learning program/format that arises directly from workplace problems and concerns (Lester & Costley, 2010). It merges conceptual theories from practice, knowledge, and experience to educate learners and ensure they meet the needs of their job requirements (Sobiechowska & Maisch, 2006). According to Sweet (2018), there are multiple benefits that businesses can acquire from work-based learning:

- Work-based learning can raise enterprise productivity and innovation;
- Work-based learning is a powerful form of pedagogy;
- Work-based learning help enhance employees' career development;
- Work-based learning improves the quality of vocational training and education.

Training methods of work-based learning

Work-based learning aims to blend the strengths of formal and informal education and provide authentic practical learning experiences. It can be learning for work, such as enrolling in college courses, or learning at work, such as attending in-house training in personal development programs. Cunningham and Dawes (2016) list thirty-seven work-based learning methods. We summarized them into four categories, shown in Table 1.

Table 1: Work-based learning methods

Category of WBL Methods	Current methods for work-based learning
Feedback/Assessment/Critique from Colleagues and experts	360 Feedback; Action Review; Benchmarking; Presentation; Consulting; Critical Friend; Discussion; Interviewing; Meetings; Peer review; Instruments; Video feedback; Video conference; Delegation from supervisor; Dialogue with colleagues and experts; Management walking about; Shadowing
Training and Education	Computer-based training; Counselling; Development center; Distance learning
Learning from current work experience	Mistakes; Observation Listening; Questioning/asking; Task group; Volunteering; Witnessing
Self-learning activities	Reading; Reflective learning; Research; Writing; Learning logs; Travel/visits; Repertory grid method

Issues of current work-based learning

Work-based learning has been very successful for over 20 years in developing employability skills for college students and employees in organizations (Brodie & Irving, 2007). It helps minimize the knowledge and skill gaps between the classroom and the workplace and ensures that employability skills are transferred to new college graduates (Konstantinou & Miller, 2021). However, current work-based learning still encounters issues that obstruct the successful fulfillment of learning for work or at work (Brook & Corbridge, 2016), especially when it mainly focuses on graduate entrants (Hamilton, 2019).

Cognitive overload. According to the information processing theory (Atkinson & Shiffrin, 1968), during the process of learning, skills and knowledge are first stored in sensory memory, which filters out some information and only passes the most important ones to the next unit, named working memory. Working memory is a short-term memory unit that will encode the impressions of the information and store it in long-term memory as either semantic memories, procedural memories, or images. Since working memory has limited capacity, a potential issue of work-based learning could be cognitive overload, which happens when the learning tasks exceed our memory processing demand capacity (Chang & Ley, 2006). Cognitive overload can cause problems in filtering, selecting, and analyzing the available information, which, in turn, leads to low learning effectiveness and high learning anxiety (Bawden & Robinson, 2009). Furthermore, cognitive load in work-based learning negatively impacts learners' engagement, self-regulated learning, and learning outcomes (Dong et al., 2020; Hughes et al., 2018). Bakar et al. (2022) argued that enhancing cognitive load could improve work-based learning. Thorvald et al. (2019) demonstrated that technology should be adopted to create a better working environment, which would help employees develop better cognitive skills in their workplace.

Scheduling. In most work-based learning methods, except self-training activities, learners need to work with others to complete the training, such as trainees, colleagues, and consultants. Therefore, scheduling the training could be hard to fit everyone's calendar, and sometimes the training has to be postponed because of the scheduling issue. This issue could delay the learning process and reduce the effectiveness of work-based learning.

Training quality. Work-based learning programs are learning activities to develop and enhance learners' ability to solve problems in their daily professional jobs (Collis & Margaryan, 2005). Work-based problems are complex and often require integrated theoretical knowledge and professional skills of workplace experience. However, when cooperating with educational institutions, some of them have limited views and expertise to develop and provide sufficient and adequate training programs. This low-quality training will weaken the training effect (Orpen, 1999). In this case, business learners will be unable to solve workplace problems after their work-based learning training (Brook & Corbridge, 2016; Garnett, 2016).

Gamification and work-based learning

Computer-based training is listed as one of the work-based learning methods (Cunningham & Dawes, 2016). It helps employees engage in repetitive job tasks, experience predicted failure, and ensure their capabilities to their job position requirements (Gupta et al., 2022). Therefore, gamification has been adopted in various workplaces and industries (Mitchell et al., 2020). Virtual Computer-aided design (CAD) training approved the efficiency of gamification applications in the manufacturing industry (Ulmer et al., 2021). In health care, Martinho et al. (2020) identified some physical, cognitive, social, and emotional benefits in supporting elderly care. Moreover, in the public sector, gamification showed the capability to address the complexity of procurement processes in employees' training (Kornevs et al., 2019).

Gamification shows the potential positive and innovative solutions to help organizations improve employees' work-based knowledge and skills with additional job engagement, loyalty, and vitality (Markopoulos et al., 2015). However, few studies have been undertaken using gamification for work-based learning purposes (Psani et al., 2020); although Buligina and Sloka (2019), and Jayalath (2021) suggest that it is a valuable training method that can overcome the issues of work-based learning and successfully achieve the purposes of training and education for work. Table 2 shows the advantages of gamification over the issues of current work-based learning.

Furthermore, gamification has several additional advantages which pertain to training small business owners in their needs. According to Knowles (1990), learning methods to educate adults should be self-directed and recognize the individual differences of the learner in terms of scheduling, place, and pace of their learning. Gamification perfectly satisfies these requirements so learners can decide when, where, and how to complete the training. Moreover, learning becomes easier and more acceptable when a learning process is divided into smaller and more manageable pieces, such as sub-skill lessons (Tóth & Tóvölgyi, 2016). Gamification uses multiple games to complete different training pieces and achieve knowledge transformation for the learners, which makes the training painless and readily available. Lastly, gamification empowers learners with flexibility in the training content they can control over their learning (Gee, 2005).

Table 2: Advantages of gamification over the issues of current work-based learning

Current issues of Work-based learning	Advantages from Gamification
Cognitive Overload	According to the cognitive theory of multimedia learning (Mayer, 2001), multimedia learning can reduce cognitive overload when dealing with complex information and concepts. Gamification adopts multimedia in the games. Therefore, it can help to diminish both cognitive overload and learner anxiety.
Scheduling	Since gamification is a self-training method, learners can take it based on their personal schedules.
Training Quality	During the development phase, all the required solutions were built into the games in the gamification. Before businesses adopt the games, they would be able to evaluate the qualification of the gamification training. Therefore, the quality of the training can be guaranteed through the training program assessment before the training starts.

Therefore, we propose that compared to traditional web design learning paths, such as in-class lectures/training and self-learning, gamified web design learning environment will improve the small business owners' learning outcomes.

RESEARCH METHOD

GAMIFICATION DESIGN

According to the literature review and our website programming teaching experiences, we designed a gamified training system, including a group of games, to help small business owners with no programming experience in web design develop their business websites. Throughout all the games, we followed the Kolb learning cycle theory (Kolb & Fry, 1975) discussed in our literature review:

1. At the beginning of each game, we briefly explain the basic concepts and knowledge;
2. We then let the users try the primary activities to earn experiences, which is in line with the first step (concrete experience) in Kolb's theory;
3. Next step, we show users the correct examples. This corresponds to the second step (reflective observation) in Kolb's theory;
4. Then, we let the users conclude and learn from experience by summarizing the knowledge, which is the third step (abstract conceptualization) in Kolb's theory;
5. Lastly, we let users try different applications by themselves in the game, which aligns with the last step (active experimentation) in Kolb's theory.

Simmons et al. (2008) proposed a conceptual model of the Determinants of Small Business Website Adoption with seven website criteria, including website design, accessibility, navigability, content for relationship enhancement, content for promotion and image, relational interactivity, and transactional interactivity. Additionally, according to Lubinsky (2018), there are six components that every business website needs to ensure success, including an elegant design, a clear call to action, a story page, organic search ranking, social proof, and mobile responsiveness. Thus, we summarized key factors supporting a successful business website, such as aesthetics, navigation, server application, content, social network, and mobile application, and developed our gamified training content. Within a game map named My Home Page Land, there are eight games (Figure 1):

1. Art & Design game: asks users to draw desired page design and identifies mistakes they made to give them a good idea of designing a user-friendly website;
2. Fighting game: includes brief training videos to teach users the basic knowledge of web programming and 20 levels of gaming tasks for each website design language technology, such as HTML, JavaScript, Python, CSS, and SQL. Each level teaches users to program several specific web design functions/commands. After users pass all the levels, they will understand how to program a website;
3. Puzzle game: helps users understand how to upload web files to a server, operate database management activities on a server, and design better navigation for a website;
4. Story development games: help users to create brand stories, missions, and vision statements;
5. Simulation of establishing social networks: guides users to build linkages between a website to popular social networks;
6. Simulation of effects on mobile devices: asks users to compare the visual effects of a website on both PCs and mobile devices and understand the mobile responsiveness of a website;
7. Simulation of translating a website to a mobile application: asks users to build a mobile application from a website design.
8. Error-correcting games: asks users to test different website designs based on organic search ranking and other website characteristics, such as spelling, grammar, and keeping up-to-date information accurately.

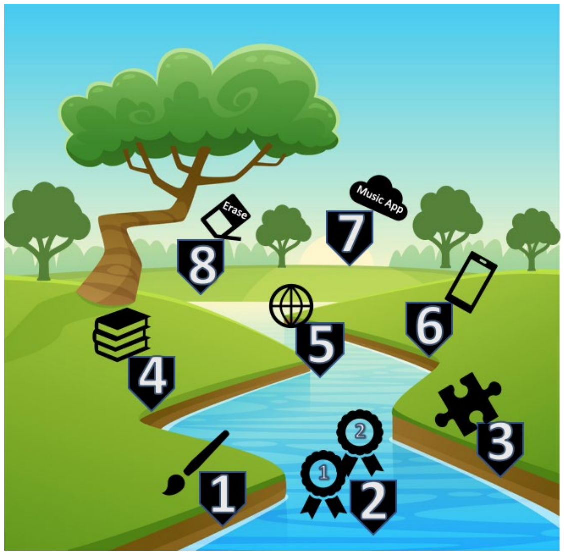

Figure 1: Web Design Learning Game Interface

These eight games not only teach learners how to design and develop their websites but also allow them to build an understanding of the key factors supporting a successful business website. Through this gamified training, small business owners will be able to design and develop their business websites and efficiently maintain and update their websites with the knowledge they learned from the eight games. Table 3 shows the learning outcomes and technologies taught in each game.

Table 3: Learning outcomes and technologies associated with each game

Game Number	Learning Outcomes	Programming Technology
1	Understand best practices that designers can consider when building user interfaces for a commercial website (the guidelines were summarized from the laws of UX, https://lawsofux.com/)	
2	Understand the basic skills of HTML, CSS, JavaScript, Python, and Microsoft SQL	HTML, CSS, Javascript, Python, and SQL Server
3	Understand the concepts and operations of client-server, how to use Microsoft SQL server management system, and basic Database SQL (language)	Server operations, and Microsoft SQL Server
4	Understand the power of storytelling in web design and the 5 P's of storytelling (People, Place, Pictures, Platforms & Personal)	
5	Understand how to link to the popular social network websites	HTML, CSS, Javascript, and Python
6	Understand the differences between a website and a mobile app from a designer's perspective	Mendix
7	Understand how to use Mendix to convert a website to an App	Mendix
8	Understand how to conduct website and mobile application testing	Web testing

RESEARCH DESIGN

Population and sampling

Through a university Small Business Center, invitation emails were sent to 87 local small business CEOs. The location is a typical small town in the south of the United States with a 90,000 population. We did not choose any small IT companies because we assumed most of their CEOs should have basic website design knowledge. Our study is looking for CEOs who have no or limited IT backgrounds. We chose companies in the non-IT industries, including manufacturing, hospitality, retail, health services, insurance, and food and restaurant. Eventually, 38 CEOs agreed to participate in our study.

Training procedure

We first asked if they would like to learn web programming by themselves. Unfortunately, none of these 38 CEOs showed any interest in the self-learning path. Therefore, we decided to compare only in-class and in-game training for web programming education. We completed the following steps for the website design training:

1. After a simple IT background review of all the CEOs, only 8 of them learned HTML at college, but they had never developed any websites by themselves;
2. We randomly divided the 8 CEOs who learned HTML into two groups (Groups 1 & 2) and the other CEOs into two groups (Groups 3 & 4). Lastly, we combined groups 1 and 3 as a new group (group A) and put CEOs from groups 2 and 4 into another new group (Group B). By doing this, we balanced the IT background of the CEOs in both final groups.
3. For Group A, we scheduled a one-month virtual training workshop (2 hours per day and 4 hours each Saturday or Sunday). Total training hours are 78 (42 hours for weekdays and 36 hours for weekends). Every day, we asked CEOs to complete a minor assignment. We would give them an e-badge every time they completed their assignment. We would award them a trophy at the end of the one-month training if they collected over 20 badges. We started the training from HTML and gradually taught the CEOs all the knowledge they needed for web design. Our training contents are identical to what we embedded into the web design learning game.
4. For Group B, we gave them a half-day virtual training on the game, such as how to use it, install it, and contact us for their questions.
5. We created 38 accounts on our training server. Then, we sent the account information to all 38 CEOs and asked them to log on to their accounts during their virtual training time to ensure they could log on to their server accounts successfully.
6. For Group B, after the half-day training, we asked the participants to start playing the web programming learning game. We told them that the system would record their learning time in the game and ask them to ensure that the total learning time should be equal to or over 78 hours during the one-month training period.
7. At the beginning of our training, we asked all CEOs to start building their business websites on a designated server, along with their training steps. We required them to record their daily working time on their business website design and development (not including their training time through the virtual workshop).
8. A month later, after both groups completed their training, we sent a short survey to all the CEOs asking questions about their training and programming experiences.

Website project requirements

To cover most of the basic needs of a typical small business website, we gave the CEOs the following requirements and asked them to try their best to complete all the requirements during this one-month website design training. We defined a completion percentage table of the time consumption of activities in a simple business website design and development (Table 4). Therefore, we could evaluate the completion status of all the CEOs after they took the training.

1. Create at least six web pages, including the Homepage, About Us page, Productions/Services page, Customer Registration/Login page, Shopping Cart/Checkout page, and Customer Account Profile page. (15%)
2. Develop a database including at least one customer table in the database. (10%)
3. Create at least one brand story and a business mission and vision statement for the business. (5%)
4. Build a customer registration/login feature (needs to connect to the database). (10%)
5. Complete at least four links to popular social media networks and the feature of customer registration associated with customer social network accounts. (10%)

6. Develop a customer shopping cart/checkout feature (connect to the database and payment validation center). (25%)
7. Translate the website to a mobile app. (25%)

Table 4: Website Design and Development Completion Percentage

	Completion percentage	Description
1	15%	Completed requirement #1
3	20%	Completed requirements #1&3
2	25%	Completed requirements #1&2
4	30%	Completed requirements #1, 2 &3
5	40%	Completed requirements #1, 2, 3 &4
6	50%	Completed requirements #1, 2, 3, 4 & 5
7	75%	Completed requirements #1, 2, 3, 4, 5 & 6
8	100%	Completed all requirements

RESULTS AND DISCUSSIONS

DESCRIPTIVE STATISTICS

Demographic variables of gender, age, and company industry are reported as follows (n=38). Only 13.2% of the CEOs were female. The age of the CEOs ranges from 18 to 67. Over 68% of CEOs are between the ages of 31 and 60. A wide variety of industries that the CEOs are currently working in were represented in the responses, as shown in Table 5.

Table 5: Demographic information of the Participants

Demographics	Percentage of participants
Gender	
Female	13.2% (n=5)
Male	86.8% (n=33)
Age	
18-30 years old	18.4% (n=7)
31-45 years old	42.1% (n=16)
46-60 years old	26.3% (n=10)
over 60	13.2% (n=5)
Industry	
Manufacturing	7.9% (n=3)
Hospitality	15.8% (n=6)
Retail	18.4% (n=7)
Health Services	21.1% (n=8)
Insurance	26.3% (n=10)
Food and Restaurant	10.5% (n=4)
Total	**100% (n=38)**

COMPARISON OF TWO GROUPS

To identify the differences between the two training groups, we conducted Independent-Samples *t*-Test. The first criterion we used in the study was the total hours each CEO spent on their website learning and development. This time includes two parts. The first part is the time each CEO spent on their website design training:

- for CEOs in Group A, this is the total time they spent on the virtual workshop (some of the CEOs did not spend 78 hours in the workshop because they had other events that conflicted with the workshop);
- for CEOs in Group B, this includes a half-day virtual workshop and the total time they spent in the training game

The second part is the time each CEO spent on their business website design and development other than the training time. Table 6 shows the average hours each CEO spent in the training (Workshop training for group A and gamified training for group B). The time spent on the training workshop in Group A ranged from 36 hours to 78 hours, indicating that some CEOs in Group A did not complete the entire training workshop hours. The numbers in Group B have a minimum of 60 hours and a maximum of 110 hours, which is definitely higher than the numbers in Group A. After adding the extra time each CEO spent on their actual business website design and development, we got the total time for CEOs working on their business website design and development. According to Table 7, CEOs from Group A averagely spent 78.9 hours total for this learning process. Obviously, CEOs from Group B averagely spent more time (100 hours) learning website design and development. The *t*-test results (Table 8) show a significant difference in the total hours spent on website design and development learning between Group A with virtual training workshop and Group B with gamified training (t=-3.30, df=36, p=0.002).

Table 6: Total time attending the training workshop or in the gamified training

	Number of Participants	Min. Hours	Max. Hours	Range (hours)	Mean (hours)	Std. Error (hours)	Std. Deviation (hours)	Variance
Total hours studied in the training workshop (group A)	19	36	78	42	64.26	2.96	12.92	166.87
Total hours spent in the game (group B)	19	60	110	50	89.37	3.32	14.47	209.24

Table 7: Total time working on the website design & development

	Group A or B	Number of Participants	Mean (hours)	Std. Deviation (hours)	Std. Error Mean (hours)
Total_hours	A	19	78.89	20.50	4.70
	B	19	100.16	18.77	4.31

Table 8: Independent Samples Test of the total hours spent by Group A and B

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Total hours	Equal variances assumed	.210	.649	-3.334	36
	Equal variances not assumed			-3.334	35.724

		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Total hours	Equal variances assumed	.002	-21.26316	6.37711	-34.19655	-8.32977
	Equal variances not assumed	.002	-21.26316	6.37711	-34.20002	-8.32630

P is significant at the 0.05 level.

The most important criterion we used to evaluate the CEOs' learning outcomes from the training programs is the completion percentage of the business websites they built right after their training. We believe that the purpose of learning website development is to actually develop the website. Therefore, this completion percentage variable will appropriately represent the CEOs' learning outcomes from the training programs we offered. According to Table 9, on average, the CEOs in Group A only completed 36.84% of their websites, whereas the CEOs in Group B completed 55.26% of their business websites. The results of a *t*-test between the two groups (Table 10) show a statistical significance for the average website completion percentage between the two groups (t=-2.330, df=36, p=0.026).

Table 9: Average Completion Percentage of both groups

	Group A or B	Number of Participants	Mean	Std. Deviation	Std. Error Mean
Completion	A	19	36.84%	21.680%	4.97%
	B	19	55.26%	26.795%	6.15%

Table 10: Independent Samples Test for average completion percentage between groups A and B

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Completion	Equal variances assumed	1.203	.280	-2.330	36
	Equal variances not assumed			-2.330	34.497

		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Completion	Equal variances assumed	.026	-.18421	.07907	-.34458	-.02384
	Equal variances not assumed	.026	-.18421	.07907	-.34482	-.02360

P is significant at the 0.05 level.

ADDITIONAL SURVEY RESULTS

Additionally, at the end of our training program, we distributed a short survey asking about the CEOs' experience with this training program. We asked three questions regarding their satisfaction with the training program, their enjoyment during the training, and their perceived usefulness of the training program. We used a 7-Point Likert Scale ranging from 1 (very strongly disagree) to 7 (very strongly agree). The results in Table 11 show that the average evaluation from group B was at least 2 Likert Scale levels higher than the average evaluation from group A. According to the results in Tables 12 to 14, all results from three survey questions show significant differences between the two groups, which indicates that CEOs from group B were more satisfied with the training (t=-4.029, df=36, p=0.000), enjoyed more with the training (t=-4.933, df=36, p=0.000), and they believed the training is useful (t=-5.737, df=36, p=0.000).

Table 11: Results Statistics of three survey questions

	Group A or B	Participants	Mean	Std. Deviation	Std. Error Mean
Are you satisfied with the training effectiveness and efficiency?	A	19	3.79	2.043	.469
	B	19	5.95	1.129	.259
Do you enjoy the training?	A	19	3.53	1.837	.421
	B	19	6.05	1.268	.291
Please evaluate the usefulness of this training	A	19	3.68	1.916	.440
	B	19	6.47	.905	.208

Table 12: Independent Samples Test for the satisfaction with the training effectiveness and efficiency between groups A and B

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Satisfaction	Equal variances assumed	13.913	.001	-4.029	36
	Equal variances not assumed			-4.029	28.054

		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Satisfaction	Equal variances assumed	.000	-2.158	.536	-3.244	-1.072
	Equal variances not assumed	.000	-2.158	.536	-3.255	-1.061

P is significant at the 0.05 level.

Table 13: Independent Samples Test for the enjoyment of the training between groups A and B

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Enjoyment	Equal variances assumed	6.595	.015	-4.933	36
	Equal variances not assumed			-4.933	31.982

		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Enjoyment	Equal variances assumed	.000	-2.526	.512	-3.565	-1.488
	Equal variances not assumed	.000	-2.526	.512	-3.569	-1.483

P is significant at the 0.05 level.

Table 14: Independent Samples Test for the usefulness of the training between group A and B

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Usefulness	Equal variances assumed	20.525	.000	-5.737	36
	Equal variances not assumed			-5.737	25.646

		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Usefulness	Equal variances assumed	.000	-2.789	.486	-3.776	-1.803
	Equal variances not assumed	.000	-2.789	.486	-3.790	-1.789

P is significant at the 0.05 level.

The following summarizes the results of this study:

- The training time of the CEOs in Group A ranged from 36 hours to 78 hours, whereas numbers in Group B ranged from 60 hours to 110 hours;
- The average time the CEOs in Group A spent on their business website design and development was 78.9 hours, whereas the average time in Group B was 100.16 hours. The t-test results show a significant difference between the two groups;
- On average, the CEOs in Group A only completed 36.84% of their websites, whereas the CEOs in Group B completed 55.26% of their business websites. The t-test results show a significant difference between the two groups;
- The t-test results show significant differences in all three survey questions from the CEOs, including satisfaction, enjoyment, and usefulness of the training, between the two groups.

Discussion

In line with the literature reviewed, it is reasonable to design and develop a desired gamified training system to support small business owners in developing a commercial website by themselves for their businesses (King, 2018). Traditional web design and development training programs challenged learners' patience, listen-to-understand reaction, and time consumption (Lareki et al., 2010). Therefore, many small business owners were afraid of website design and development (Chinomona, 2013). This study compared a gamified training program with traditional in-class training. The learning outcomes and survey results from two groups of small business CEOs showed statistically significant differences. The results support our proposed assumption that gamified web design learning environment improves small business owners' learning outcomes.

First, although the traditional training in our study was virtual, the average time the CEOs attended the training was 64 hours out of the complete 78 hours of the training (Table 6). However, the CEOs who participated in the gamified training program spent an average of 89 hours in their training. Because we arranged and scheduled this training program with all 38 CEOs two months before the actual training time, we believe that the reasons for the CEOs to leave the in-class training mostly are not because of their business or preplanned personal events. To identify the actual causes, we did a short follow-up interview with each CEO recently. 81% of the CEOs, who spent less than 78 hours for training in Group A, admitted their absence from the training was mainly because it was hard to learn so much information about website development, and their interest in the training dramatically decreased when they faced the program bugs. Only 32% of the CEOs in Group B gave similar reasons for their absence from the training. In addition, the CEOs gave relatively low evaluations of the traditional training programs on their perception of satisfaction, enjoyment, and usefulness in the survey. In light of the results from the survey and the follow-up interviews, we argue that the main reason the CEOs in group A, on average, spent much less time on the training is that the in-class training itself is not attractive. On the contrary, the CEOs in group B showed more enthusiasm in attending the gamified training and gave very positive evaluations on the three survey questions. From a theoretical perspective, according to the cognitive load theory, cognitive load negatively influences self-regulated learning (Dong et al., 2020; Hughes et al., 2018). In this study, the high cognitive load of web development knowledge decreased the CEOs' self-regulated learning in group A. In contrast, the gamified training for group B enhanced the CEOs' cognitive load, and this group could tolerate and accept more information from the training. This could explain the differences between the two groups. Therefore, we believe that the gamified training program attracts more users spending a relatively long time.

Second, besides the training program, we also asked all CEOs to spend extra time developing their business website based on their training content. We calculated the total hours (we named it Total Hours of Learning) each CEO spent on training and business website development. We believe that the number of total hours of learning reveals the CEOs' efforts in learning website design and development. Therefore, we used linear regression to analyze the relationship between the completion of the website (dependent variable) and the total hours of learning (independent variable). The results align with our expectations that the relationship is statistically significant, $p<.000$, with an R^2 of 0.48 (Table 15). This finding concurs with the common argument that the more time applied to website development, the higher the completion percentage the CEOs would get at the end of the training.

Table 15: Relationship between total hours of learning and website completion percentage

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.704[a]	.496	.482	.18563	.496	35.411	1	36	.000

a. Predictors: (Constant), Total_hours

Third, from a business perspective, website completion is the aim of website design and development. Therefore, we used the website completion percentage to evaluate the CEOs' final training outcomes after the training program. The statistical results (Tables 9 & 10) supported our hypothesis that gamified web design learning environment improves the small business owners' learning outcomes compared to traditional web design learning paths, such as in-class lectures/training.

Fourth, we noticed significant differences in learning satisfaction, enjoyment, and usefulness through our short survey results between the two training groups (Tables 12 to 14). These results suggest that our gamified training system surpasses the traditional lecture training method from a learner's perspective. This result is also in line with the argument from Markopoulos et al. (2015) that gamification enhances learners' engagement.

Additionally, we asked the CEOs to explain why none of them showed any interest in the self-learning path at the beginning of this study. Their reasons are listed in Table 16.

87% of the CEOs were not encouraged to learn by themselves because of the difficulty of web development. 18 CEOs (47% of the total) tried to learn and stopped eventually, which indicates that almost half of the CEOs believed this web development knowledge was necessary to the workplace. However, they quit due to the difficulty of learning. Therefore, we can argue that, in self-learning, one of the work-based learning methods, learners lack motivation with a perceived learning difficulty.

Table 16: Reasons not to attend the self-training

Number of CEOs	Reason not to do self-learning	Percentage
33	Too difficult to learn (18 of them tried before but failed)	87%
2	No time	5%
3	Don't know how to start	8%

The following information summarizes our findings:

- Gamified training program improves small business owners' learning outcomes;
- Gamified training program attracts more users spending a relatively long time in the training;
- Gamified training program provides better support to users in learning website design and development;
- Gamified training program enhances learners' engagement;
- Self-learners lack motivation with a perceived learning difficulty.

CONCLUSIONS

Work-based learning has the potential to help employees develop their desired skills and gain knowledge in their workplace (Brook & Corbridge, 2016). However, with several key issues, such as cognitive overload, scheduling, and training quality, work-based learning may not be an appropriate method to support small business owners in learning. As Cardador et al. (2017) indicates, gamification is a promising training method, which shifts in-class or mentored training to self-direct training with a motivation mechanism adopted from game features.

This study compares two website design and development training methods, work-based in-class training and gamification training, in the specific context of small business owners' perspectives. To our best knowledge, this is the first study in the field that developed a research model regarding gamification to help business owners develop their own websites effectively. We designed a gamified training program for small business owners to help them easily understand how to design and develop their business websites. We scheduled a one-month training for 38 small business owners using the traditional lecture training method and our gamified training system. The results confirm that our gamified training program gains higher learning outcomes and better learning satisfaction. The results of this study help advance the understanding of training program design and provide insights to support small business owners in learning new technologies.

This research has made considerable contributions to, and implications for, research. First, this study developed a new gamified training system to help researchers study the differences between traditional in-class training and gamified programs. This system covers the essential training activities of learning website design and development. Researchers can use this system to test more research models and theories. Second, this study empirically compared traditional work-based lecture training and gamified training methods. The results highlight the significant differences between the two training methods. For any work-based training and education programs, researchers should take the gamified system into consideration. Lastly, most researchers investigate either website design and development learning or business activities of small business owners. Few studies have investigated the need for website knowledge training and education of small business owners. The outcomes of this study suggests areas for future research by combining technology education and small business owners' needs in their workplace.

Our study offers several implications for practice. First, the gamified training program provides better user support in learning website design and development compared to traditional training methods. Software developers in training and education can offer easier and more efficient tools for various training and education programs using gamified systems. Second, with the growth of technologies, small business owners are challenged when they are trying to efficiently absorb new technologies or up-to-date IT-related knowledge (Leonard-Barton & Kraus, 1985). The results of this study show the advantages of gamified training programs. For their future training program selections, small business owners should pay more attention to and explore the benefits of gamified training and education systems in the market.

Moreover, our results may have broader educational implications. Appropriate training design would improve employees' work-based skills and training involvement, thereby arousing their desire to study (Chung et al., 2019). Therefore, the results of this study can provide substantial help for instructional designers to understand the efficiency and effectiveness of the gamified training method, which could assist them in designing more appropriate and accessible training programs. Additionally, current educational work-based training has often been copied from university education programs, although the programs seem to simulate the settings close to the working environment (Tell & Gabrielsson, 2013). More and more researchers argue that educators should understand the small business circumstances and integrate business learning culture into the work-based training pedagogy (Greenbank, 2000). Therefore, special structured educational programs, such as the gamified training program in this study, should be adopted for small businesses to enhance business management education under their learning culture, especially for managers who have never had a traditional university education.

There are some inherent limitations in our study. First, none of these 38 CEOs paid any interest in the self-learning path. Therefore, this study only compares in-class and gamified training for web programming education. We do not know the effects of the self-learning path, though we discussed the direct reasons and potential causes above. We suggest that further research should compare all these three learning methods.

Second, all the CEOs who participated in this study are from one city in the USA. Analytical results presented may therefore have limited generalizability. We plan to expand this study to several metropolitan cities, such as New York, Los Angeles, and Chicago. The results would be more acceptable from a generalization perspective.

Additionally, the generalizability of the results to other countries might be limited due to cultural differences. Cultural differences could raise obstacles and problems during work-based learning (Doherty & Stephens, 2020). Hofstede (1997) defines culture as a system of patterns that differentiates people into groups with five dimensions: power distance, uncertainty avoidance, individualism versus collectivism, masculinity versus femininity, and long-term versus short-term. In gamification training, individual cultural differences may cause learning barriers to the learners while using the training program without customized cultural settings. From an organizational perspective, learners may be confused or even resistant to the training if the gamification training is incompatible with the organizational culture to support its accepted values, ideas, and beliefs (Ferrara, 2013). Therefore, further investigations can be carried out to identify the culture construct in the context of gamification applications in small business work-based training programs.

Future research should also be conducted to explore to what extent gamification can improve work-based learning and what are the primary factors in the gamification design.

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THE MODERATING EFFECTS OF GENDER ON FACTORS AFFECTING THE INTENTION TO USE MOBILE LEARNING

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ABSTRACT

Aim/Purpose	The main aims of this research are to explore the moderating effects of gender on the relationships of such factors and the intention to use mobile learning, to examine the factors that influence m-learning acceptance in the universities and higher education institutions (HEI) in Iraq, and to investigate the influence of the intention to use on the actual use of mobile learning in (HEI).
Background	Over recent decades, mobile learning has played an increasingly important role in the teaching and learning process, especially for higher education. As such, acceptance and use of mobile learning has become a topic of interest within the education sector. In this regard, UTAUT is one of the widely used models for examining users' intention for use and acceptance of information technology.
Methodology	A survey method was used in this study involving a sample of 323 participants recruited from several universities in Iraq.
Contribution	This study has made significant contributions to the advancement of m-learning in Iraq by developing a mobile learning model that can help guide practitioners to promote and facilitate the use of such an approach in universities.
Findings	The findings showed that gender moderated the relationships of social influence (SI), effort expectancy (EE), and performance expectancy (PE) with respondents' intention to use m-learning. In addition, the findings confirmed the perceived enjoyment, performance expectancy (PE), effort expectancy (EE), self-efficacy (SE), and social influence (SI) had significant direct effects on intention to use m-learning. Furthermore, the respondents' intention to use or behavioral intention had a significant impact on the actual use of m-learning.

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Recommendations for Practitioners	It is vital for university management and practitioners to encourage students about the advantages of mobile learning in higher education institutions. In Iraq, the research in mobile learning is still very new and there are few studies have analyzed the gender effect on the mobile technology acceptance in learning. This study provides a roadmap of the gender effect on variables that could influence mobile learning acceptance in higher education institutions in Iraq.
Recommendations for Researchers	The gender moderation effect on the factors that influence the mobile learning acceptance is important, thus the new researchers are advised to examine the gender effect on other factors that could influence mobile learning acceptance. Moreover, cross-nation studies are needed to further validate the findings of this research because it was conducted from the perspective of a developing nation where mobile learning is still in its infancy. Future studies may broaden the research to examine additional potential elements, such as the quality of services in future models, which can help enhance the understanding of learners' acceptance and continuous usage of mobile learning as well as to improve the utility of UTAUT.
Impact on Society	The use of mobile learning has increased in its importance for higher education around the globe, including Iraq. Clearly, mobile learning has been pervasively used in education throughout the world due to the Covid-19 pandemic. During this time, students were required to study at home for months as per governments' orders in order to avoid being affected by the virus. With mobile learning, students were able to continue their studies; otherwise, they would have missed the academic year. Academic staff and administrators should therefore encourage and employ mobile learning for instruction, student communication, and exam administration.
Future Research	Given that the UTAUT model was used in higher educational settings for this research, it is advised to look into its application in corporate settings to see if comparable results can be repeated or not. More research is advised to look at the moderating effects of demographic factors, such as age and place of origin, in order to shed more light on students' adoption of mobile learning in HEIs in developing nations.
Keywords	Iraq, M-learning acceptance, gender moderator, HEI

INTRODUCTION

The objective of this study is to examine the gender moderation effect on the variables that influence the acceptance of m-learning and investigate the factors that influence the m-learning acceptance in the higher education institutions (HEI) in Iraq. Mobile learning is becoming a crucial part of education in a bid to promote learning interactions (Izkair & Lakulu, 2021). Mobile learning has certainly been proven to be the most effective teaching strategy for informal education when compared to other methods (Izkair et al., 2020). ICT is an effective tool for advancing formative objectives since it is a powerful enabler for boosting communication and information sharing (Alharmoodi & Lakulu, 2020). The rapid and expanding development of ICT and mobile technologies has led to the development and widespread adoption of new applications and innovative services. Thus, the analysis of the variables that may affect instructors' intentions to employ mobile learning in HEI is critical from a teaching standpoint (Althunibat, 2015).

Most universities in Iraq have some barriers to educational advancement, and practitioners need innovative technologies to meet these challenges, such as the strength of ICT infrastructure and internet connection to promote improved user satisfaction (Mohammed et al., 2015; Morad, 2019; Wahsh & Dhillon, 2015). According to the literature, mobile learning could be used as a novel technology to supplement traditional education. Mobile devices with print-based interfaces offer more comfort, mobility, and convenience compared to personal computers (Neumann & Neumann, 2014) that are suited for younger users, require less effort, and promote continuity and spontaneous learning (Kukulska-Hulme, 2009). In this regard, M. Mohamad et al. (2012) identified the affordances of flexible, efficient applications that were able to assist underperforming learners by supporting individualized learning environments. Moreover, such novel applications can help support many learning styles, both formal and informal (A. J. Mohamad et al., 2016). Over recent years, numerous organizations have focused their efforts on helping their clients take advantage of the rapidly developing computerized technology (A. J. Mohamad & Lakulu, 2017).

In this study, the factors affecting acceptance of m-learning are identified, these factors will be used to determine whether gender significantly affects acceptance levels by means of a questionnaire administered to 323 participants selected from several universities in Iraq. Moreover, this research will investigate the influence of m-learning acceptance on the m-learning actual use.

RELATED WORKS

The focus of purposeful mobile learning usage, mobile learning challenges and UTAUT Model as well as the variables that influence the behavioral intention to utilize mobile learning is discussed in this section. This section also elaborates the effects of gender on the relationships between such variables and intention to use mobile learning.

THE ACCEPTANCE OF M-LEARNING

By including educators in the learning process, one of the pillars of integrating modern innovations into the e-learning strategy is gaining their acceptance. To help realize this, it is crucial to understand the key factors influencing technological acceptance so that their impacts can be assessed, measured, and predicted more precisely (Sánchez-Prieto et al., 2016).

THE ACCEPTANCE AND USAGE

According to a study by Mohammadi (2015) that focused on earlier studies using TAM, intention is defined as the likelihood that a person would use an information system. It has been identified as the most important variable pertaining to technology acceptance. Additionally, the intention to use is seen as a crucial component in really putting new innovations to use (F. D. Davis, 1989). Practically, it is difficult to anticipate that a particular attitude toward a modern innovation will also result in the use of that innovation. However, several studies, such as those of Iqbal and Bhatti (2017), and Martins et al. (2014) showed a positive relationship between intention to use and actual use of innovation.

MOBILE LEARNING CHALLENGES

The transition of e-learning into mobile learning that takes into account their integration process entails the influences of difficulties in the process of transformation additionally. The possible difficulties could be the compatibility flaws within the database, educational issues, mobile devices penetrating capability, customer acceptance, pressures encountered at open and social levels, and many other problems. Even the lecturers may feel reluctant to adapt to the imperatives of mobile innovation as its use in learning encounters requires additional effort (Abu-Al-Aish & Love, 2013; Althunibat, 2015).

The effective performance of mobile learning setting also requires a diversity of talented people in using the mobile device in an arrangement to access educational materials provided by mobile learning, and is ready for using services of the mobile learning. If higher education institutions fail to cope with the difficulties of mobile learning implementation, important problems with the acceptance of learners in the mobile learning usage are likely to arise. Chen and Denoyelles (2013) discussed this issue that despite the existing research extent of mobile learning approach in universities.

Therefore, issues of mobile learning implementation require examining, like students' acceptance. This study is based on identifying the variables that influence mobile learning acceptance as experienced by the students at university. The research analyzes the current investigations conducted in this regard (Althunibat, 2015).

Mobile learning is widely used in well-established countries in term of infrastructure and internet connection as well as the facilitating conditions that help in using the technology. However, when it comes to the developing countries and in particular to Iraq, the use of mobile learning is minimal and this is due to several issues such as the perception of students about the benefit and the ease of using mobile learning as well as the strength of the infrastructure and the internet connection and user satisfaction (Mohammed et al., 2015; Morad, 2019; Wahsh & Dhillon, 2015).

Smartphones can do many of the functions of a computer and their usage in everyday life activities is obvious. Nevertheless, in Iraq, the adoption of technology is still in the range of 20% and students have preference to the traditional method (Al-Azawei & Alowayr, 2020; Alsswey et al., 2020; Okai-Ugbaje et al., 2020). For this reason, the study will attempt understanding the factors that lead to the increase in the adoption of mobile learning in Iraqi higher education institutions, and investigate the gender effect on the relationships of some factors on m-learning acceptance in HEI.

Review of the UTAUT Model in Mobile Learning Acceptance

Abu-Al-Aish and Love (2013) study mentioned the various models that have been developed to investigate the intention and acceptance of individuals for adoption of modern innovations in the information systems at the world. F. D. Davis (1989) attempted to identify the reasons why individuals acknowledge the innovation of data.

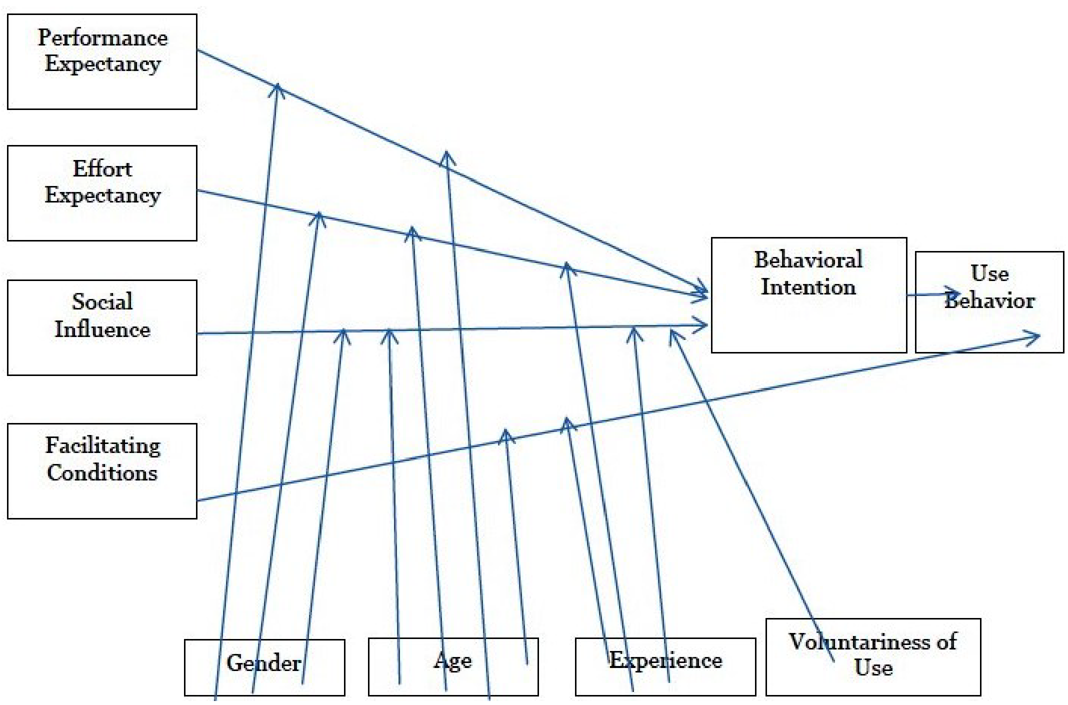

Figure 1: The UTAUT Model (Venkatesh et al., 2003)

Technology acceptance model (TAM) is the most widely used model in the area of technology adoption (F. D. Davis et al., 1989). The concept of TAM is to provide a theoretical base to clarify the effect of external factors (i.e., training, computer self-efficacy, objective system design features) on attitude toward use, internal beliefs, behavioural intentions, and actual use of systems. Another well-known and modern model in acceptance of the information technology is the "unified theory of acceptance and use of technology" (UTAUT). This model was proposed by Venkatesh et al. (2003) and seeks to consolidate and empirically compare components from different innovation acceptance models in innovation acceptance. Figure 1 shows The UTAUT model.

The UTAUT has four determinants of IT user behaviour and four moderators that are found to moderate the influence of the four determinants on the user behaviour and behaviour intention. UTAUT theorizes that effort expectancy, performance expectancy, facilitating conditions and social influence are direct determinants of behaviour intention or user behaviour.

The moderating variables (age, gender, voluntariness of use and experience) are crucial for influencing the behaviour of various customers groups (see Figure 1). Venkatesh et al. (2003) showed that UTAUT has the capability to demonstrate about 70% of variance in the intention. It has been shown that UTAUT outperforms the previous models (Venkatesh et al., 2003). Moreover, it could give a valuable device for supervisors to evaluate the success of the modern innovation (Ibrahim & Jaafar, 2011).

Variables Selected for the Research

Previous investigations have found various variables, such as performance expectancy, effort expectancy, social influence, quality of service, perceived enjoyment, and self-efficacy, are significant determinants of technology acceptance. Table 1 shows the six variables selected for this study along with related prior research for each variable, and the studies of the gender moderation effect.

Table 1: Factors affecting the intention to use m-learning and the gender moderation effect

No.	Independent Factors	Studies
1	Performance expectancy	Abu-Al-Aish & Love, 2013), (Chaka & Govender, 2017), (Huan et al., 2015), (Milošević et al., 2015)
2	Effort expectancy	(Abu-Al-Aish & Love, 2013), (Chaka & Govender, 2017), (Huan et al., 2015), (Milošević et al., 2015),
3	Social influence	(Briz-Ponce et al., 2017), (Chaka & Govender, 2017), (Huan et al., 2015), (Sabah, 2016), (Tan et al., 2014)
4	Quality of Service	(Abu-Al-Aish & Love, 2013), (Althunibat, 2015), (Huan et al., 2015), (Milošević et al., 2015)
5	Perceived enjoyment	(Y. M. Cheng, 2015), (Huan et al., 2015), (Poong et al., 2017)
6	Self-efficacy	(Huan et al., 2015), (Mohammadi, 2015)
7	Gender moderation effects	(Alasmari, 2020), (Camilleri, 2019), (Y. S. Cheng et al., 2011), (J. L. Davis & Davis, 2007), (Ghalandari, 2012), (Morris & Venkatesh, 2000), (Ong & Lai, 2006), (Sun & Zhang, 2006), (Wang et al., 2009), (Zhang, 2005), (Zhou & Xu, 2007).

Variables Influencing Mobile Acceptance:

Many studies have been discussed and investigated that focused on the mobile learning acceptance to identify the important factors or variables that influence the m-learning acceptance. From the literature review, 12 studies have been selected, which include the factors that influence mobile learning acceptance. In this study, six factors were chosen that affect the intention to use mobile learning in HEI in Iraq.

This section will show the six variables that could affect the intention to use mobile learning or the mobile learning acceptance. These factors lead to the first research hypotheses of this study, the factors influencing acceptance of m-learning.

Performance expectancy

Users' levels of acceptance and use of new technology that will help them succeed in their work are described as performance expectancy (Alshammari, 2021; Venkatesh et al., 2003).

"H1: Performance expectancy has a significant and positive effect on intention to use mobile learning."

Effort expectancy

According to a study by Milošević et al. (2015), effort expectancy is regarded as a vital element of information systems that demonstrates the degree of certainty of mastering an innovation (Marchewka & Kostiwa, 2007). Additionally, effort expectancy is defined as the degree of comfort associated with system usage (Alshehri et al., 2020; Venkatesh et al., 2003).

"H2: Effort expectancy has a significant and positive effect on intention to use mobile learning."

Social influence

In terms of modern innovation and social effect, social influence can be defined as the extent to which a person's perception of the use of a modern innovation is dependent on other people's perceptions of its significance (Venkatesh et al., 2003).

"H3: Social influence has a significant and positive effect on intention to use mobile learning."

Quality of services

According to a study by (Milošević et al., 2015), most definitions of quality of services place a strong emphasis on the client's comprehension and satisfaction with the services received. The client's demand for service quality was described in (Parasuraman et al., 1988) study as what the client believed would provide him or her with this advantage rather than what it actually did. As cited in a study by (Azeez & Lakulu, 2018), Shareef et al. (2014) and Al-Hubaishi et al. (2017) attempted to set the standards for the quality of mobile services, which saw the latter defining quality standards from a quality perspective.

"H4: Quality of services has a significant and positive effect on intention to use mobile learning."

Perceived enjoyment

According to a study by (Poong et al., 2017), ICT and PC use have changed over the past decades from being mostly used for work to combining work and leisure activities. This huge leap in use has been fascinated by the advancement of innovation, which has resulted in smaller and cheaper PCs as well as greater computer mobility. In this respect, (Alrfooh & Lakulu, 2020) assert that perceived enjoyment is an important factor that has a significant impact on leaners' intentions to use mobile learning.

"H5: Perceived enjoyment has a significant and positive effect on intention to use mobile learning."

Self-efficacy

Self-efficacy could be characterized as a person's belief in the value of utilizing a certain technology or system. According to Abbad et al. (2009), a user's perception of his or her ability to engage in particular behaviors, such as the ability to carry out particular obligations, can be described as self-efficacy (Ali & Arshad, 2016). Without a doubt, prior research has shown that a user's acceptance of information and communication technology is strongly influenced by their level of computer self-efficacy (ICT).

"H6: Self-efficacy has a significant and positive effect on intention to use mobile learning."

Actual usage and acceptance

According to Mohammadi (2015), intention (which has been identified as one of the significant determinants of actual use in earlier studies) is defined as the likelihood that a person will use an information system. In order for a modern breakthrough to be actually used, its approval is crucial (F. D. Davis, 1989). Clearly, the practical application of a given innovation depends on the user's behavioral intention toward that innovation (F. D. Davis et al., 1989; Iqbal & Bhatti, 2017).

"H7. Intention to use has a significant and positive effect on actual use of mobile learning."

MODERATING EFFECTS OF GENDER

In past studies, such as those of Ong and Lai (2006) and Wang et al. (2009), gender differences were examined in relation to factors influencing the acceptance of m-learning and e-learning., earlier studies on the gender differences in attitudes toward and acceptance of mobile learning frameworks yielded contradictory results. Previous studies on the use of mobile learning in various contexts, such as businesses, colleges, and schools, found that male users had significantly more favorable perceptions of mobile learning and e-learning than female users (e.g. Ong & Lai, 2006; Zhou & Xu, 2007).

By contrast, several researchers, including J. L. Davis and Davis (2007) and Zhang (2005), noted there are no differences in gender regarding such perceptions. Other studies have produced contradicting findings regarding gender's moderating influences on the variables that affect technology acceptance. For example, male behavioral intentions were strongly influenced by perceived usefulness, as shown in studies by (Morris & Venkatesh, 2000; Sun & Zhang, 2006), whereas female behavioral intentions were significantly impacted by perceived ease of use, as found in a study by (Ong & Lai, 2006).

According to Camilleri (2019), performance expectancy appears to be a strong determinant of the adoption of mobile learning, and the intensity of the relationship varies by gender, being more significant for males and younger respondents. Moreover, the association between effort expectancy and acceptance was moderated by gender, with older respondents and female respondents placing greater importance on this factor. However, those effects tend to fade over time.

According to Y. S. Cheng et al. (2011), gender was a significant moderator that affected the relationship between behavioral intention and social influence, and it particularly affected young females, where the association was stronger. It would seem that when a tool for mobile learning is offered, young females would be more likely to have a stronger intention to use it than males. Therefore, it is recommended that male students and older students should motivate themselves more to improve their behavioral intention to use mobile learning.

According to Ghalandari (2012), gender had moderating effects on the relationships between social influence, effort expectancy, and performance expectancy with users' acceptance. According to Alasmari (2020), female academics regarded mobile learning as an easy means to access resources and course materials whenever and wherever they chose, as well as a tool to complete assignments and make up for missed lectures.

"H8: Gender is a moderating variable affecting the influence of performance expectancy on intention to use mobile learning."

"H9: Gender is a moderating variable affecting the influence of effort expectancy on intention to use mobile learning."

"H10: Gender is a moderating variable affecting the influence of social influence on intention to use mobile learning."

RESEARCH METHODOLOGY

Research methodology is crucial because it directs a methodical investigation of a phenomenon. It offers the researcher a suitable step-by-step procedure to aid in achieving the research objectives.

QUANTITATIVE RESEARCH APPROACH

The proper selection of research subjects by the researcher is the first step in conducting a quantitative study. In this quantitative study the researchers use self-administered questionnaires for individuals, which have been verified through a variety of tests (Choy, 2014; Dudwick et al., 2006). Of course, according to the research gap, it is the basic for creating a particular framework (Husain et al., 2017). They are 323 completed surveys.

QUESTIONNAIRE DEVELOPMENT

In the first stage of data gathering and management, Iraqi students and academics in HEIs who had experience with mobile learning were surveyed. The target audiences were three public universities in central Iraq. Sections A, B, and C made up the three sections of the questionnaire. The demographic information of the respondents, such as gender and educational level, was gathered through Section A. While Section B sought respondents' opinions on the benefits of mobile learning, Section C gathered information relating to the research constructs. See the appendix of this research in the end of this study that has 38 questions, each factors has 3-5 questions. Figure 2 shows the survey development.

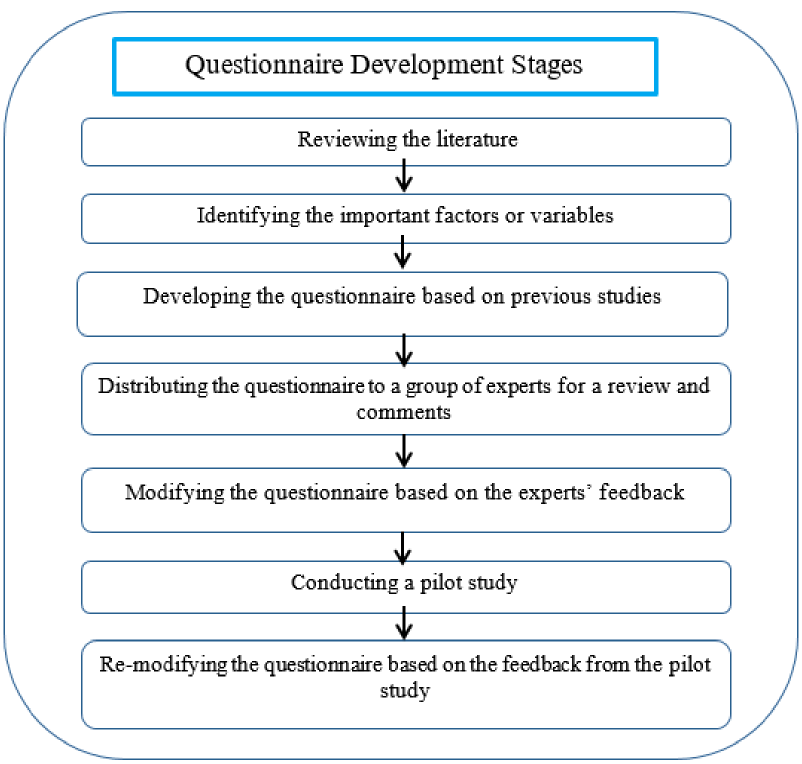

Figure 2: The questionnaire development stages

Data Analysis

The survey data elicited from 323 complete questionnaires were analyzed using SPSS statistical software and the AMOS program to yield descriptive statistics (means and frequencies) and inferential statistics. To make sure the analysis would produce accurate results, missing data, normality, and multi-collinearity were verified beforehand (Yin, 2009). Specifically, the AMOS program was used for data analysis to test the research hypotheses.

Research Hypotheses

In this study, seven research hypotheses were formulated to examine the direct relationships between the study constructs. Also, another three research hypotheses were developed to examine the moderating effects of gender on the relationships between performance expectancy, effort expectancy, and social influence with the intention to use mobile learning. Table 2 summarizes all the 10 research hypotheses of this study.

Table 2: Research Hypotheses

#	**Hypotheses**
1.	"H1: Performance expectancy has a significant and positive effect on intention to use of mobile learning"
2.	"H2: Effort expectancy has a significant and positive effect on intention to use of mobile learning"
3.	"H3: Social influence has a significant and positive effect on intention to use of mobile learning"
4.	"H4: Quality of services has a significant and positive effect on intention to use mobile learning"
5.	"H5: Perceived enjoyment has a significant and positive effect on intention to use mobile learning"
6.	"H6: Self-efficacy has a significant and positive effect on intention to use mobile learning"
7.	"H7. Intention to use has a significant and positive effect on actual use of mobile learning"
8.	"H8: Gender is a moderating variable affecting the influence of performance expectancy on intention to use mobile learning"
9.	"H9: Gender is a moderating variable affecting the influence of effort expectancy on intention to use mobile learning"
10.	"H10: Gender is a moderating variable affecting the influence of social influence on intention to use mobile learning"

Model Validation

Ten experts with experience in m-learning and information technology were given a second questionnaire to complete in order to verify that the mobile learning model of this study was valid. These experts were lecturers from several institutions in Malaysia and Iraq. The experts were specifically chosen because of their vast expertise in the field of and deep interest in mobile learning. The researcher gave the experts a briefing on the variables, objectives, and developed model of the study. The objective of the second questionnaire was to collect comments and suggestions from the experts to help verify the validity of the variables that were used to create the model for this study. Table 3 shows the demographic background of the experts selected in this study.

Table 3: The demographic background of experts

Experts	Position	University	Expertise	Years of Experience
Expert 1	Associate Professor	University of Babylon-Iraq	Information Technology	More than 20 years
Expert 2	Senior Lecturer	University of Babylon-Iraq	Information Technology	More than 15 years
Expert 3	Professor	University of Technology – Iraq	Information System	More than 25 years
Expert 4	Associate Professor	Sultan Idris Education University – Malaysia	Mobile Learning	More than 20 years
Expert 5	Associate Professor	Almustaqbal University College- Iraq	Mobile Learning & E-Governance	More than 15 years
Expert 6	Senior Lecturer	University of Technology – Iraq	Mobile Learning	More than 10 years
Expert 7	Associate Professor	University of Babylon-Iraq	Information System	More than 20 years
Expert 8	Senior Lecturer	University of Technology – Iraq	Information System	More than 10 years
Expert 9	Associate Professor	Sultan Idris Education University – Malaysia	Mobile Learning	More than 15 years
Expert 10	Professor	University of Babylon-Iraq	Information Technology	More than 22 years

DATA ANALYSIS AND FINDINGS

In this study, the SPSS and AMOS statistical software were used for analyzing the data gathered from the survey.

MISSING VALUES

The frequency analysis carried out on all the items entered into SPSS was used to look at missing values. Hair et al. (2017) state that a response should be deleted if its missing values are greater than 15%. However, mean score values can be used to replace missing values that are under 15%. There were no missing values for any of the survey responses in this study, according to the results of the frequency analysis in SPSS. This was mostly attributed to the use of online questionnaires, which prevented respondents from sending incomplete questionnaires. Additionally, every question had the word "required" next to it. With 323 survey responses obtained from the respondents, the response rate was therefore calculated to be 100%.

NORMALITY

Both (Hair et al., 2017) and (Pallant, 2016) note that there are two methods for determining normality. The first method is to check the skewness and kurtosis. Since this method is widely accepted and the values of kurtosis and skewness are less than 2, it can be concluded that the data of this study were normally distributed (George & Mallery, 2008). The second method used involved examining the histograms of the study variables.

A bell-shaped pattern is an example of a normal distribution. Table 4 displays the skewness and kurtosis of the data, with values for skewness that were less than 2 and between -.030 and -.525 in range. Additionally, the range of kurtosis values is below 2 and lies between .415 and 1.128.

Table 4: The Analysis of Normality

Factor	Skewness1 <±2	Kurtosis1 <±2
"Social Influence"	-.182	-.680
"Perceived Enjoyment"	-.216	-.929
"Effort Expectancy"	-.374	-.536
Quality of Service	-.525	-.805
Performance Expectancy	-.323	-.762
Self-Efficacy	-.251	-.959
Intention to Use	-.030	-1.128
Actual Use	-.137	-.922
Standard error of Skewness	.137	
Standard error of Kurtosis		.274

The distribution of the data was normal, as shown in Table 2, supporting the assumption that the data were normally distributed. Additionally, the histogram of each variable was examined visually, which revealed a bell-shaped distribution of the data.

Demographic Profile of Respondents

Table 5 summarizes the demographic profiles of the respondents in terms of gender, age grouping, educational background, and length of time utilizing mobile learning. Descriptive statistics, such as means and standard deviations, are also displayed in the table.

The gender breakdown of the study's respondents is shown in Table 5 below. It shows that 165 respondents, or 52.5% of them, were men and 149 respondents, or 47.5%, were women. This suggests that the study had a nearly equal representation of both genders.

Table 5: Demographic profiles of respondents

Variable	Label	Frequency	Percent	Mean	Std
Gender	Male	165	52.5	1.47	.500
	Female	149	47.5		
"Age" (years)	"19-26"	37	11.8	2.62	.988
	"27-34"	110	35.0		
	"35-42"	114	36.3		
	"43-50"	40	12.7		
	">50"	13	4.1		
Education	Bachelor	97	30.9	2.56	1.144
	Diploma	13	4.1		
	Master	135	43.0		
	PhD	69	22.0		
Experience (years)	"0-4"	171	54.5	1.48	.549
	"5-8"	135	43.0		
	"9-12"	8	2.5		

STRUCTURAL MODELS

The third level of the SEM-AMOS program, which comprises three levels, deals with structural models. The structural model was tested using the SEM approach, which was also utilized to look at each hypothesis's significance levels and path coefficients (Sabah, 2016). At this point, the hypotheses were tested, showing the values of the model's R-square. The structural model for this investigation is shown in Figure 1. As a dependent variable with an R-square of 0.60, intention to use can be explained by the independent variables, namely PE, SI, satisfaction, perceived enjoyment, personal inventiveness, FC, self-efficacy, EE, and quality of service, for 60% of the variance.

The study's dependent variable, intention to use (ITU), had an R-square of 0.6, meaning that the study's independent variables, including perceived enjoyment (PE), personal innovativeness (SI), satisfaction, self-efficacy (FC), quality of service, and effort expectancy, explained 60% of the variance in ITU. The R-square for AU was 0.44 as well, indicating that ITU accounted for 44% of the variance of actual use.

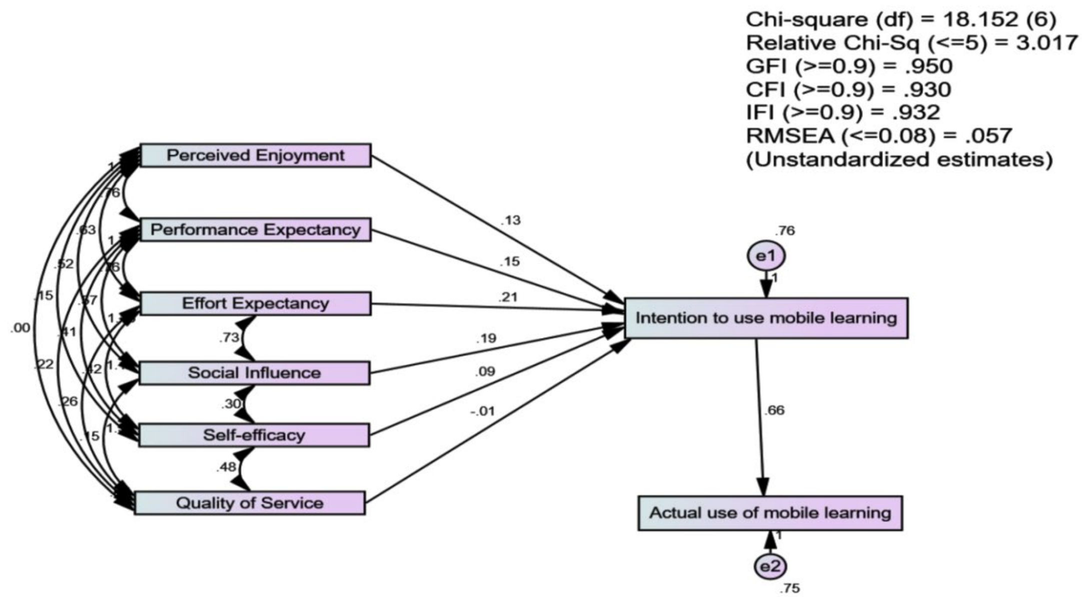

Figure 3: Structural Model of Direct Effect

The aforementioned R-square values were deemed acceptable by Hair et al. (2017). R-square values between 0.25 and 0.50 are considered good, while those between 0.50 and 0.75 are regarded as exceptional. Figure 3 shows the structural model for the current investigation that was applied in Iraq. In this study, the mean score values were utilized to examine the indirect and direct effects of the independent variables. This approach is in line with other studies that used the mean score values to examine structural models, including those of Hair et al. (2010), Awang (2014), and Lowry and Gaskin (2014).

HYPOTHESES TESTING

The study comprised seven research hypotheses that dealt with direct effects of the independent variables and three research hypotheses that focused on the moderating effects of gender. In the sections that follow, the discussion of the latter hypotheses is preceded by a discussion of the former hypotheses.

DIRECT EFFECTS OF THE INDEPENDENT VARIABLES

The findings of testing the first seven research hypotheses are summarized in Table 6 in terms of path, degree of significance (P), estimate (B), critical ratio (C.R.) or t-value (T), and standard error (S.E.). According to (Hair et al., 2010), the p-value (also known as significance level) must be lower than 0.05 and the C.R. must be higher than 1.96 in order to accept a hypothesis (Awang, 2014).

Table 6: The Findings of Direct Influence for Hypotheses

"IV"	"Path"	"DV"	"P"	"Estimate (B)"	"C.R."	"S.E."	"H"	"Out-come"
"PE"	--->	"ITU"	.002	.152	3.096	.048	"H17"	"Ac-cepted"
"EE"	--->	"ITU"	***	.206	4.216	.048	"H26"	"Ac-cepted"
"SI"	--->	"ITU"	***	.196	3.806	.052	"H34"	"Ac-cepted"
"QOS"	--->	"ITU"	.798	-.012	-.256	.046	"H46"	"Re-jected"
"PEN"	--->	"ITU"	.021	.118	2.316	.051	"H58"	"Ac-cepted"
"SE"	--->	"ITU"	.030	.090	2.165	.042	"H64"	"Ac-cepted"
"ITU"	--->	"AU"	***	.661	15.811	.041	"H73"	"Ac-cepted"

Legend: ITU: intention to use; PE: performance expectancy; EE: effort expectancy; SI: social influence; QOS: quality of service; PEN: perceived enjoyment; SE: self-efficacy; and AU: actual use.

TESTING THE MODERATING EFFECTS OF GENDER

The gender of the respondents, from which the data were spilt into male and female categories, was proposed as the moderator in this study. The number of men was 165, while the number of women was 149. Accordingly, two structural models were developed for the analysis, with the first being constrained while the second being unconstrained. Comparisons of chi-square test values were made between the constrained and unconstrained models, indicating that there was a significant moderating effect if the difference in such values was more than 3.84 (Awang, 2014). The chi-square test is a nonparametric test that is employed for two distinct purposes: (a) testing the null hypothesis that there is no association between two or more groups, populations, or criteria (i.e., determining the independence between two variables); and (b) determining the likelihood that the observed data distribution matches the expected distribution (i.e., determining the goodness-of-fit). Categorical data analysis is done using it (e.g. male or female students, etc.) (Rana & Singhal, 2015). The following sections discuss the moderating effects of gender on the relationships between SI, EE and PE with ITU.

MODERATING EFFECT OF GENDER ON THE RELATIONSHIP BETWEEN PERFORMANCE EXPECTANCY AND INTENTION TO USE

The eighth research hypothesis, H8, postulates that gender moderates the impact of performance expectancy (PE) on intention to use mobile learning (ITU) in Higher Education Institution (HEH) in Iraq. Specifically, this hypothesis states that gender is a moderating variable affecting the influence of performance expectancy on intention to use mobile learning in higher education institutions (HEI). Table 7 summarizes the results of the Chi-square test in testing this research hypothesis based on the constrained and unconstrained models for females.

Table 7: Results of Chi-square test of the models for the relationship between PE and ITU for females

"Type1 of model/high"	"P"	"CMIN"	"CMIN/DF"	"DF"	"NPAR"	"Model"
Constrained	.000	107.805	10.781	10	56	"Defaults models"
		.000		0	66	"Saturated models"
	.000	726.747	13.214	55	11	"Independences models"
Unconstrained	.400	9.414	1.046	9	57	"Defaults models"
		.000		0	66	"Saturated models"
	.000	726.747	13.214	55	11	"Independences models"

The difference in the Chi-square values of the unconstrained and constrained models was examined to test the significance of the moderating effect of gender, as summarized in Table 8. It is evident that there was a significant moderating effect of gender on the relationship between PE and ITU for females as the difference between the chi-square values was more than 3.84.

Table 8: Result of moderating effect of gender on the relationship between PE and ITU for females

"High"	"Unconstrained Model"	"Constrained model"	"Chi-square differences"	"Result of moderation"	"Result of hypothesis"
"Chi-square"	9.414	107.805	98.391	Significant	Accepted
"DF"	9	10	1		
"GFI"	.989	.908			
"CFI"	.999	.954			
"IFI"	.999	.964			
"RMSEA"	.018	.257			
"Chi-square/df"	1.046	10.781			
"H8: Gender is a moderating variable affecting the influence of performance expectancy on intention to use of mobile learning"					Accepted

Table 9 summarizes the results of the Chi-square test in testing this research hypothesis based on the constrained and unconstrained models for males.

Table 9: Chi-square test results of the models involving PE and ITU for males

"Type of model/low"	"P"	"CMIN"	"CMIN/DF"	"DF"	"NPAR"	"Model"
Constrained	.000	143.248	14.325	10	56	"Defaults models"
		.000		0	66	"Saturated models"
	.000	745.057	13.546	55	11	"Independences models"
Unconstrained	.000	33.370	3.708	9	57	"Defaults models"
		.000		0	66	"Saturated models"
	.000	745.057	13.546	55	11	"Independences models"

Table 10 shows the results of moderating effect of gender on the relationship between performance expectancy and intention to use mobile learning for males. As shown, the difference in the Chi-square values was 109.878, which is greater than 3.84, thus providing the evidence to support this research hypothesis.

Table 10: Result of moderating effect of gender on the relationship between PE and ITU for males

"Low"	"Unconstrained Model"	"Constrained model"	"Chi-square differences"	"Result of moderation"	"Result of hypothesis"
"Chi-square"	33.370	143.248	109.878	Significant	Accepted
"DF"	9	10	1		
"GFI"	.968	.905			
"CFI"	.965	.907			
"IFI"	.967	.919			
"RMSEA"	.128	.285			
"Chi-square/df"	3.708	14.325			
"H8: Gender is a moderating variable affecting the influence of performance expectancy on the intention to use mobile learning"					Accepted

The unconstrained paths (PE on ITU) for males and females were looked into in order to determine whether the effects of the moderator were significant or not, as shown in Table 11. As shown, the moderating effects were highly significant for both genders, as the significance values (p-values) of both paths were less than .05. Therefore, there was strong evidence to accept the eight research hypothesis, H8, of the study.

Table 11: The significance of the moderator for the relationship between PE and ITU

"Model"	"IV"	"Path"	"DV"	"P"	"Estimate"	"C.R."	"S.E."	"Outcome"
Female	PE	--->	ITU	.024	.161	2.265	.071	Accepted
Male	PE	--->	ITU	.042	.140	2.034	.069	Accepted

Moderating Effect of Gender on the Relationship Between Effort Expectancy and Intention to Use

The ninth research hypothesis, H9, of this study proposes that gender is a moderator for the relationship between effort expectancy (EE) and intention to use (ITU). Specifically, it is expressed as gender is a moderating variable affecting the influence of effort expectancy on intention to use mobile learning. Table 12 summarizes the results of Chi-square test in testing this research hypothesis based on the constrained and unconstrained models for females.

Table 12: Results of Chi-square test of the models for the relationship between EE and ITU for females

"Type of model/high"	**"P"**	**"CMIN"**	**"CMIN/DF"**	**"DF"**	**"NPAR"**	**"Model"**
Constrained	.000	108.753	10.875	10	56	"Defaults models"
		.000		0	66	"Saturated models"
	.000	726.747	13.214	55	11	"Independences models"
Unconstrained	.400	9.414	1.046	9	57	"Defaults models"
		.000		0	66	"Saturated models"
	.000	726.747	13.214	55	11	"Independences models"

Table 13 summarizes the results of the moderating effect of gender. As shown, it is clear that there was a significant moderating effect of gender on the relationship between EE and ITU for females as the difference between the chi-square values was more than 3.84.

Table 13: Result of moderating effect of gender on the relationship between EE and ITU for females

"High"	**"Unconstrained Model"**	**"Constrained model"**	**"Chi-square differences"**	**"Result of moderation"**	**"Result of hypothesis"**
"Chi-square"	9.414	108.753	99.339	Significant	Accepted
"DF"	9	10	1		
"GFI"	.989	.908			
"CFI"	.999	.953			
"IFI"	.999	.962			
"RMSEA"	.018	.258			
"Chi-square/df"	1.046	10.875			
"H9: Gender is a moderating variable affecting the influence of effort expectancy on intention to use mobile learning"					Accepted

Table 14 summarizes the results of Chi-square test in testing this research hypothesis based on the constrained and unconstrained models for males.

Table 14: Results of Chi-square test of the models for the relationship between EE and ITU for males

"Type of model/low"	"P"	"CMIN"	"CMIN/DF"	"DF"	"NPAR"	"Model"
Constrained	.000	124.901	12.490	10	56	"Defaults models"
		.000		0	66	"Saturated models"
	.000	745.057	13.546	55	11	"Independences models"
Unconstrained	.000	33.370	3.708	9	57	"Defaults models"
		.000		0	66	"Saturated models"
	.000	745.057	13.546	55	11	"Independences models"

Table 15 shows the results of moderating effect of gender on the relationship between effort expectancy and intention to use mobile learning for males. As shown, the difference in the Chi-square values was 91.531, which is greater than 3.84, indicating that the moderating effect was significant.

Table 15: Result of moderating effect of gender on the relationship between EE and ITU for males

"Low"	"Unconstrained Model"	"Constrained model"	"Chi-square differences"	"Result of moderation"	"Result of hypothesis"
"Chi-square"	33.370	124.901	91.531	Significant	Accepted
"DF"	9	10	1		
"GFI"	.968	.908			
"CFI"	.965	.933			
"IFI"	.967	.944			
"RMSEA"	.128	.265			
"Chi-square/df"	3.708	12.265			
"H9: Gender is a moderating variable affecting the influence of effort expectancy on intention to use mobile learning"					Accepted

The unconstrained paths (EE on ITU) for males and females were examined to determine whether the effects of the moderator were significant or not, as shown in Table 16. As indicated, the moderating effects were highly significant for both genders, as the significance values (p-values) of both paths were less than .05. Therefore, there was strong evidence to support the ninth research hypothesis, H9, of the study which is H9: Gender is a moderating variable affecting the influence of effort expectancy on intention to use mobile learning.

Table 16: The significance of the moderator for the relationship between EE and ITU

"Model"	"IV"	"Path"	"DV"	"P"	"Estimate"	"C.R."	"S.E."	"Outcome"
Female	EE	--->	ITU	.000	.220	3.354	.066	Accepted
Male	EE	--->	ITU	.007	.196	2.700	.073	Accepted

MODERATING EFFECT OF GENDER ON THE RELATIONSHIP BETWEEN SOCIAL INFLUENCES AND INTENTION TO USE

The tenth research hypothesis of this study states that gender is a moderator for the relationship between social influence (SI) and intention to use (ITU). Specifically, it is expressed as gender is a moderating variable affecting the influence of social influence on intention to use mobile learning. Table 17 summarizes the results of Chi-square tests in testing this research hypothesis based on the constrained and unconstrained models for females.

Table 17: Results of Chi-square test of the models for the relationship between SI and ITU for females

"Type1 of model/high"	"P"	"CMIN"	"CMIN/DF"	"DF"	"NPAR"	"Model"
Constrained	.000	86.536	8.654	10	56	"Defaults models"
		.000		0	66	"Saturated models"
	.000	726.747	13.214	55	11	"Independences models"
Unconstrained	.400	9.414	1.046	9	57	"Defaults models"
		.000		0	66	"Saturated models"
	.000	726.747	13.214	55	11	"Independences models"

Table 18 summarizes the results of the moderating effect of gender. As shown, it is clear that there was a significant moderating effect of gender on the relationship between SI and ITU for females as the difference between the chi-square values was 77.122, which is more than 3.84

Table 18: Result of moderating effect of gender on the relationship between SI and ITU for females

"High"	"Unconstrained Model"	"Constrained model"	"Chi-square differences"	"Result of moderation"	"Result of hypothesis"
"Chi-square"	9.414	86.536	77.122	Significant	Accepted
"DF"	9	10	1		
"GFI"	.989	.922			
"CFI"	.999	.986			
"IFI"	.999	.993			
"RMSEA"	.018	.227			
"Chi-square/df"	1.046	8.654			
"H10: Gender is a moderating variable affecting the influence of social influence on intention to use mobile learning"					Accepted

Table 19 summarizes the results of Chi-square tests in testing this research hypothesis based on the constrained and unconstrained models for males.

Table 19: Chi-square test results of the models involving SI and ITU for males

"Type of model/low"	"P"	"CMIN"	"CMIN/DF"	"DF"	"NPAR"	"Model"
Constrained	.000	139.099	13.910	10	56	"Defaults models"
		.000		0	66	"Saturated models"
	.000	745.057	13.546	55	11	"Independences models"
Unconstrained	.000	33.370	3.708	9	57	"Defaults models"
		.000		0	66	"Saturated models"
	.000	745.057	13.546	55	11	"Independences models"

Table 20 shows the results of moderating effect of gender on the relationship between effort expectancy and intention to use mobile learning for males. As shown, the difference in the Chi-square values was 105.729, which is greater than 3.84, indicating the moderating effect was significant.

Table 20: Result of moderating effect of gender on the relationship between SI and ITU for males

"Low"	"Unconstrained Model"	"Constrained model"	"Chi-square differences"	"Result of moderation"	"Result of hypothesis"
"Chi-square"	33.370	139.099	105.729	Significant	Accepted
"DF"	9	10	1		
"GFI"	.968	.905			
"CFI"	.965	.913			
"IFI"	.967	.924			
"RMSEA"	.128	.281			
"Chi-square/df"	3.708	13.910			
"H10: Gender is a moderating variable affecting the influence of social influence on intention to use mobile learning"					Accepted

The unconstrained paths (SI on ITU) for males and females were examined to determine whether the effects of the moderator were significant or not, as shown in Table 21. As indicated, the moderating effects were highly significant for both genders, as the significance values (p-values) of both paths were less than .05. Therefore, there was strong evidence to support the tenth research hypothesis, H10, of the study.

Table 21: The significance of moderators for the relationship between SI and ITU

"Model"	"IV"	"Path"	"DV"	"P"	"Estimate"	"C.R."	"S.E."	"Outcome"
Female	SI	--->	ITU	.011	.201	2.532	.079	Accepted
Male	SI	--->	ITU	.010	.174	2.265	.068	Accepted

Figure 4 shows the moderating effects of gender on the relationships between the independent variables (PE, EE, and SI) and intention to use m-learning in HEIs in Iraq.

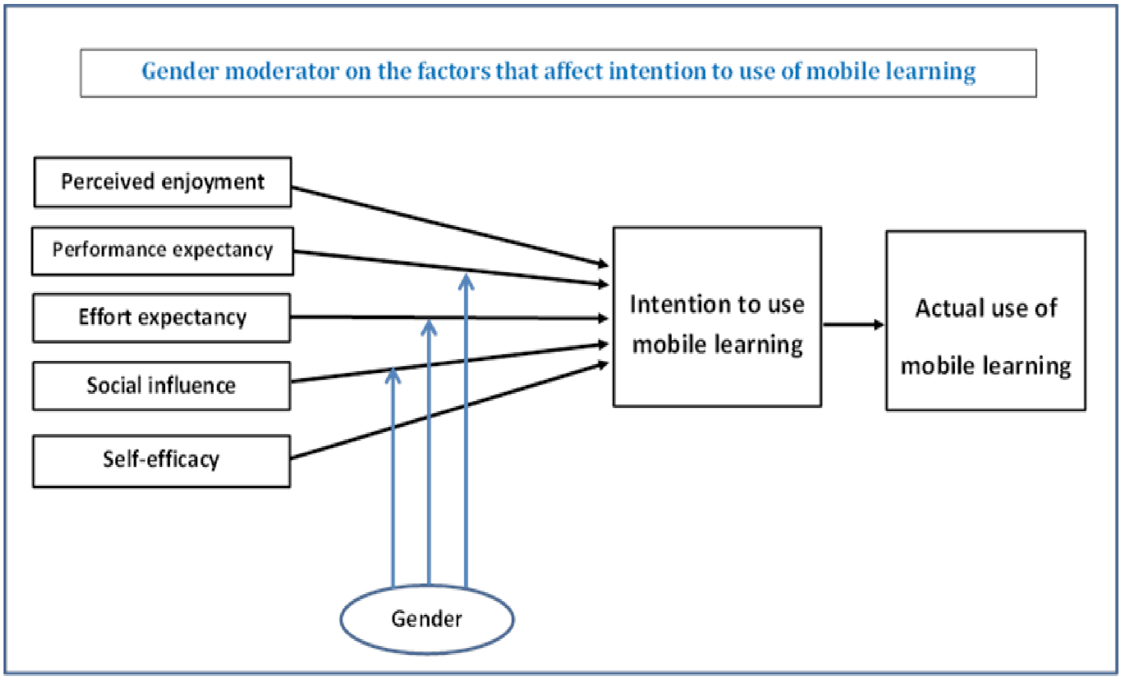

Figure 4. Moderating effects of gender on the relationships between the independent variables (PE, EE, and SI) and intention to use m-learning

DISCUSSION

This section discusses the results obtained in this study. The main three objectives of this research are to explore the moderating effects of the gender on the relationships of such factors and the intention to use mobile learning, examine the factors that influence m-learning acceptance in higher education institutions (HEI) in Iraq, and to investigate the influence of the intention to use on the actual use of mobile learning in HEI. The result of this study confirmed that gender moderated the effect of "Performance expectancy", "Effort Expectancy" and "Social Influence" on the intention to use (ITU) of mobile learning. See Figure 4 for more explanation. In addition to that, from six proposed factors in this study, five factors only are identified as influencing factors on intention to use mobile learning in HEI in Iraq, the factors are "Effort Expectancy", "Performance expectancy", "Social Influence", "Perceived Enjoyment", and "Self-efficacy", while this study discovered that "Quality of Service" is not affected on intention to use mobile learning. This study confirmed that intention to use is positively influencing the actual use mobile learning in HEI in Iraq.

DIRECT EFFECTS

Seven research hypotheses that focus on the direct effects of the independent variables were developed for this study. According to Hair et al. (2010), and Awang (2014), a research hypothesis will be accepted if the significance level, or p-value, is less than 0.05 and the critical ratio, C.R., is more than 1.96.

Performance expectancy and intention to use

The finding of hypothesis testing for the first research hypothesis was found to be significant and positive (B=0.151, C.R.=3.097, P=0.002). Therefore, the first hypothesis, or H1, of this study, which states that performance expectancy (PE) has a significant and positive effect on intention to use mobile learning, was accepted. This finding is consistent with those of previous studies (Abu-Al-Aish & Love, 2013; Chong et al., 2011; Milošević et al., 2015; Venkatesh et al., 2003; Wang et al., 2009), suggesting that performance expectancy (PE) has the strongest influence on intention to use mobile learning. Essentially, this means that it is deemed to be the most significant predictor of the intended behavior of learners in mobile learning. (Milošević et al., 2015).

Effort expectancy and intention to use

The second research hypothesis, H2, states that effort expectancy (EE) has a significant and positive effect on intention to use mobile learning. The finding of hypothesis testing for H2 was found to be significant and positive (B=0.205, C.R.=4.217, P<0.001), thus supporting the researcher with the evidence to accept the second research hypothesis. Such a finding signifies that EE has a strong influence on intention to use mobile learning among Iraqi university students. This finding is consistent with the findings of previous studies (Chong et al., 2011; Liu et al., 2010; Marchewka & Kostiwa, 2007; Venkatesh et al., 2003; Wang et al., 2009), underscoring the assertion that EE is a significant determinant of students' intention to use mobile learning.

Social influences and intention to use

The third research hypothesis, H3, of this study posits that social influence (SI) has a significant impact on the intention to use mobile learning. The results of the hypothesis testing were observed to be significant and positive (B=0.195, C.R.=3.807, P0.001), indicating that the intention to use m-learning among the respondents was heavily influenced by SI. This result effectively emphasizes that SI is a strong predictor of students' intentions to adopt mobile learning in Iraqi universities, thus supporting the study's third research hypothesis. This result concurs with the findings of earlier studies, demonstrating that social influence plays a substantial role in determining a user's behavioral intention to use new, novel innovations (Harrison et al., 1997; Venkatesh & Davis, 2000). From an educational perspective, social influence influences students' intentions to use mobile learning in a positive way (Ali & Arshad, 2016).

Quality of services and intention to use

The fourth research hypothesis, H4, of this study predicts that the influence of quality of service on the intention to use mobile learning is positive and significant. The result of hypothesis testing showed that the prediction was not true. This result showed that the C.R. of the effect was -0.256, which is less than 1.96, and the p-value was 0.798, which is greater than 0.05, indicating that the influence of quality of service on intention to use mobile learning among Iraqi universities was not significant, thus providing no evidence to support the fourth research hypothesis. Clearly, this finding conflicts with those of other studies, which revealed that service quality had a moderate impact on the intention to utilize mobile learning (Almaiah & Alismaiel, 2019) and was a deciding factor for that intention (Abu-Al-Aish & Love, 2013; Al-Zoubi, 2016; Chong et al., 2011; Park et al., 2012; Ramayah et al., 2010).

Perceived enjoyment and intention to use

When a person performs or participates in an activity because he or she is interested in it, this is referred to as perceived enjoyment (Moon & Kim, 2001). Numerous studies have demonstrated that behavioral intention to utilize mobile services, including mobile learning, is significantly influenced by perceived enjoyment (Huang et al., 2007; Wang et al., 2009). Making learning activities more enjoyable can therefore help to encourage greater adoption and use of m-learning among students. Perceived enjoyment was also treated as one of the independent variables of this study due to its strong impact on behavioral intention (Huan et al., 2015). The fifth research hypothesis, H5, posits that perceived enjoyment has a significant influence on the intention to use m-learning among Iraqi university students. The finding of hypotheses testing showed this hypothesis could be supported (B=0.118, C.R.=2.316, P=0.021), as the p-value is less than 0.05. As demonstrated, perceived enjoyment significantly influenced respondents' intentions to employ mobile learning, thus supporting the fifth research hypothesis. This finding runs parallel with the findings of earlier studies, such as that of (Poong et al., 2017), who found that perceived enjoyment was a significant factor directly impacting the intention to utilize mobile learning.

Self-efficacy and intention to use

The sixth research hypothesis, H6, of this study states that self-efficacy has a positive effect on intention to use mobile learning. The result of hypothesis testing showed the direct effect of the former on the latter was significant and positive (B=0.090, C.R.=2.165, P=0.030). This finding verified that self-efficacy was a significant predictor of intention to use m-learning among the Iraqi respondents, thus providing the evidence to support the sixth research hypothesis of the study. This finding is consistent with those of previous studies, including that of Mohammadi (2015), which observed self-efficacy was a significant variable that affected the intention of learners to use and adopt mobile learning. The acceptance of the sixth research hypothesis was further supported by other studies of various mobile learning contexts, including those of Al-Harbi (2011), Chen and Tseng (2012), Chiu and Tsai (2014), Chu (2010), Kao et al. (2011), Kreijns et al. (2013), Lee et al. (2011), Liang et al. (2011), Mahat et al. (2012), Ozdamli and Uzunboylu (2015), and Park et al. (2012), who collectively assert that self-efficacy and intention to use mobile learning are closely related.

Actual use and intention to use

The seventh research hypothesis, H7, predicts that actual use is affected significantly and positively by intention to use m-learning among the Iraqi university students. The finding of hypothesis testing showed that the direct effect of intention to use on actual use of mobile learning was positive and significant (B=0.660, C.R.=15.812, P<0.001). As such, this finding provides strong evidence to support the seventh research hypothesis of the study. This finding is consistent with that of a study by Iqbal and Bhatti (2017), who found individuals' actual behaviors were heavily influenced by their intentions to use new technology. Additionally, several earlier studies, including that of Martins et al. (2014), indicated a positive association between the two constructs.

MODERATING EFFECTS OF GENDER

To investigate the moderating effects of gender on the correlations between the research constructs, two models—one constrained and the other unconstrained—were developed. The dataset was divided into two datasets for the analysis, one for females and the other for males. The Chi-square test is typically employed to compare the outcomes of constrained versus unconstrained models. Based on the difference in Chi-square values between the two models, the moderating effects are confirmed. According to Awang (2014), a significant moderating effect is indicated by a difference in such values that is more than 3.84. The following sections discuss the results of the Chi-square tests carried out in this study to analyze the moderating effects of gender on the correlations between PE, EE, and SI with ITU.

Moderating effect of gender on the relationship between performance expectancy and intention to use

The eighth research hypothesis, H8, posits that gender moderates the influence of performance expectancy (PE) on intention to use m-learning (ITU) among Iraqi university students. The significance of such an effect was analyzed by examining the unconstrained and constrained paths of PE on ITU for females and males. As revealed, the estimates for both paths for female and male respondents were significant. As such, the eight research hypothesis of this study was supported, indicating that gender moderated the effect of PE on ITU. This result supports earlier research's findings (Camilleri, 2019; Venkatesh et al., 2003) that showed performance expectancy was a key predictor of intention to use new technologies in many contexts, with the relationship between the two constructs being stronger for men and younger users. Additionally, the results of Afonso et al. (2012), who found that performance expectancy had a significant positive impact on usage intention, particularly for men as compared to women, are in line with this study.

Moderating effect of gender on the relationship between effort expectancy and intention to use

The study's ninth research hypothesis, H9, posits that gender is a significant moderator for the relationship between effort expectancy (EE) and intention to use mobile learning. The results of testing this hypothesis showed that there were significant effects of EE on intention to use mobile learning for both females and males. In other words, the effects of EE on respondents' intentions to adopt mobile learning were strongly moderated by gender, thus supporting the ninth research hypothesis of the study. This finding is in line with those of other studies (Camilleri, 2019; Venkatesh et al., 2003), which showed that effort expectancy had an impact on behavioral intention and that this relationship was moderated by gender, especially for female respondents. This finding is also consistent with that of a study by Dulle and Minishi-Majanja (2011), who found that gender was a significant moderator that moderated the influence of effort expectancy on respondents' behavioral intention.

Moderating effect of gender on the relationship between social influences and intention to use

The tenth research hypothesis predicts that gender is a moderating variable affecting the influence of social influence (SI) on intention to use mobile learning. The results of testing this hypothesis showed that the moderating effect of gender on the relationship between SI and intention to use mobile learning was significant. In other words, among Iraqi university students, gender moderated the impact of SI on their propensity to adopt mobile learning, thus supporting the study's tenth research hypothesis. This result is consistent with that of Sabah (2016), who found significant gender disparities in how users perceive SI. Additionally, this result is in line with those of previous studies, such as Morris et al. (2005), Ong and Lai (2006), Tarhini et al. (2014), and Terzis and Economides (2011). Overall, this finding suggests that women are more likely than men to be influenced by the opinions of others and to succumb to peer pressure. From the perspective of learning, female students will be more inclined to use mobile learning if they perceive others think they should use.

CONCLUSION

The main objectives of this study are to investigate the gender moderating effect on the relationships of such factors and the intention to use m-learning, to examine the factors that influence m-learning acceptance in the universities and higher education institutions (HEI) in Iraq, and to investigate the influence of the intention to use on the actual use of mobile learning in (HEI). The findings demonstrated that among Iraqi university students' gender significantly moderated the influences of effort expectancy, performance expectancy, and social influence on students' intentions to adopt mobile learning. Moreover, the research revealed the five constructs– perceived enjoyment, effort expectancy, performance expectancy, social impact, and self-efficacy – are important determinants of intention to use mobile learning. However, the construct 'quality of services' was shown to have no significant impact. The results also clarified that the actual use of mobile learning was significantly influenced by the intention to use it.

Through this study, several contributions can be made to the field of technology acceptance by highlighting the crucial factors influencing university students' intentions to use m-learning in higher education institutions (HEIs) in Iraq. For the purpose of encouraging students and other users to consider mobile learning as an effective learning technique in education, several recommendations were made to institutions and practitioners. Given the dearth of studies in this area in developing nations, especially those in the Middle East, this study helped provide more empirical support to the existing literature, thereby enhancing the body of knowledge on technological adoption.

In view of the inherent limitations of this study, future studies can be carried out to better understand the acceptance of mobile learning among students in HEIs in developing countries by focusing on the moderating effects of other demographic variables, such as place of origin and age, on the relationships of the aforementioned determinants and students' intentions to use such a learning approach (Gan, 2016; Kim et al., 2015).

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APPENDIX

THE MAIN SURVEY (QUESTIONNAIRE)

Questionnaire Objectives

This questionnaire has these objectives:

- **To explore the moderating effects of gender on the relationships of such factors and intention to use mobile learning.**
- **To identify the factors that influence the intention to use mobile learning in HEI.**
- **To identify the influence of the intention to use on the actual use of mobile learning.**

Section A: Profile of respondents

1. What is your gender?

- Male
- Female

2. What is your age?

- 19-26 years old
- 27-34 years old
- 35-42 years old
- 43-50 years old
- More than 50

3. What is your educational level?

- Bachelor
- Diploma
- Master
- PHD

4. How long have you been using mobile learning?

- 0-3 years
- 4-7 years
- 8-11 years
- 12-15 years
- More than 15 years

Section B: The factors that influence the intention to use mobile learning in HEI.

1. Performance expectancy

5. PE1. I find mobile learning useful for my studies.

Strongly agree Agree Neutral Disagree Strongly Disagree

6. PE2. Using mobile learning would enable me to achieve learning tasks more quickly.

Strongly agree Agree Neutral Disagree Strongly Disagree

7. PE3. Mobile learning could improve my collaboration with classmates.

Strongly agree Agree Neutral Disagree Strongly Disagree

8. PE4. Mobile devices can assist me to receive assignments/home works/quizzes from my lecturers and can also assist me to submit the same to them.

Strongly agree Agree Neutral Disagree Strongly Disagree

9. PE5. Mobile devices can assist my lecturers to upload learning materials to the internet for me and can also assist me to download the same from the internet.

Strongly agree Agree Neutral Disagree Strongly Disagree

2. Effort expectancy

10. EE1. I would find a mobile learning system flexible and easy to use.

Strongly agree Agree Neutral Disagree Strongly Disagree

11. EE2. Learning to operate a mobile learning system does not require much effort.

Strongly agree Agree Neutral Disagree Strongly Disagree

12. EE3. My interaction with the mobile learning system would be clear and understandable.

Strongly agree Agree Neutral Disagree Strongly Disagree

13. EE4. It would be easy for me to become skillful at using mobile learning system.

Strongly agree Agree Neutral Disagree Strongly Disagree

3. Social influence

14. SI1. I would use the mobile learning system if my lecturers recommend and support using it.

Strongly agree Agree Neutral Disagree Strongly Disagree

15. SI2. I would use the mobile learning system if my colleagues will think that I should use it.

Strongly agree Agree Neutral Disagree Strongly Disagree

16. SI3. I would use the mobile learning system if people who are important to me will think that I should use it.

Strongly agree Agree Neutral Disagree Strongly Disagree

17. SI4. I would use the mobile learning system if my college encourages and supports using it.

Strongly agree Agree Neutral Disagree Strongly Disagree

4. Quality of Service

18. QoS1. It is important for mobile learning services to increase the quality of learning.

Strongly agree Agree Neutral Disagree Strongly Disagree

19. QoS2. I would prefer mobile learning services to be accurate and reliable.

Strongly agree Agree Neutral Disagree Strongly Disagree

20. QoS3. It is important for mobile learning to focus on the speed of browsing the internet and obtaining information quickly.

Strongly agree Agree Neutral Disagree Strongly Disagree

21. QoS4. It is important to have a user-friendly interface.

Strongly agree Agree Neutral Disagree Strongly Disagree

5. Perceived enjoyment

22. PEn1. I would find using mobile learning would stimulate my curiosity.

Strongly agree Agree Neutral Disagree Strongly Disagree

23. PEn2. I would find using mobile learning to solve problems would be appealing to me.

Strongly agree Agree Neutral Disagree Strongly Disagree

24. PEn3. I would find using mobile learning would lead to my exploration.

Strongly agree Agree Neutral Disagree Strongly Disagree

25. PEn4. I find using mobile learning to be enjoyable.

Strongly agree Agree Neutral Disagree Strongly Disagree

6. Self-efficacy

26. SE1. I could complete a job or task using a mobile device if someone showed how to do it first.

Strongly agree Agree Neutral Disagree Strongly Disagree

27. SE2. I am confident in using mobile learning if I have only the online instruction for reference

Strongly agree Agree Neutral Disagree Strongly Disagree

28. SE3. I am confident in using mobile learning even if there is no one around to show me how to use it

Strongly agree Agree Neutral Disagree Strongly Disagree

29. SE4. I am confident in using mobile learning even if I have never used such a system before

Strongly agree Agree Neutral Disagree Strongly Disagree

Section C: The intention to use mobile learning and the actual use mobile learning in HEI.

7. Intention to use mobile learning

30. ITU1. I plan to use mobile learning in my studies.

Strongly agree Agree Neutral Disagree Strongly Disagree

31. ITU2. I predict that I will use mobile learning frequently.

Strongly agree Agree Neutral Disagree Strongly Disagree

32. ITU3. I intend to increase my use of mobile services in the future.

Strongly agree Agree Neutral Disagree Strongly Disagree

33. ITU4. I will enjoy using mobile learning systems.

Strongly agree Agree Neutral Disagree Strongly Disagree

34. ITU5. I would recommend others to use mobile learning systems.

Strongly agree Agree Neutral Disagree Strongly Disagree

8. Actual use of mobile learning

35. AU1. I frequently access the course website/learning management system using a mobile device.

Strongly agree Agree Neutral Disagree Strongly Disagree

36. AU2. I frequently access course material (pdf file/PowerPoint presentation) using a mobile device.

Strongly agree Agree Neutral Disagree Strongly Disagree

37. AU3. I frequently send SMS/MMS messages to my classmates regarding class contents/information.

Strongly agree Agree Neutral Disagree Strongly Disagree

38. AU4. I frequently receive a message (SMS/MMS) from my university related to classes and/or university announcements.

Strongly agree Agree Neutral Disagree Strongly Disagree

Thank you very much for your time and effort in fulfilling this research endeavor.

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LET'S GET READY FOR WORK – EMPLOYABILITY SKILLS DEVELOPMENT IN AN IS CAPSTONE PROJECT

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ABSTRACT

Aim/Purpose	This study aims to explore undergraduate IS students' employability skills development while performing their final capstone project during their academic studies.
Background	The importance of soft skills in the Information Systems industry is not an arguable fact and has been broadly discussed both in the industry and the academic literature. The ability of professionals to collaborate, communicate, manage time, negotiate, solve problems, make decisions, and self-learning, called employability skills, are essential skills needed in today's industry. The development of these skills during undergraduate studies is essential for graduate students' readiness for work.
Methodology	A mixed methods approach was employed using exploratory research design, including qualitative and quantitative approaches. First, a qualitative analysis of 156 reflections was performed, resulting in the conceptual framework of facets. Then, a quantitative analysis of the data was performed to examine the facets and the differences between the stages of the capstone project.
Contribution	This study contributes to both academy and industry. The former may use this study's findings to upgrade academy courses and capstone projects in order to raise students' readiness for the industry. The later may learn the approaches the academy use and give appropriate feedback.

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Findings	The results showed that students' reflections on their motivation, knowledge, and skills (teamwork, time management, and inter-communication) demonstrate the importance of those facets in the process they underwent, especially since the reflections collected were unstructured.
Recommendations for Practitioners	Information Systems undergraduate academic programs should develop structured capstone projects to provide the students with a better platform to learn and experience the employability skills the industry requires.
Recommendations for Researchers	The study presents a conceptual model based on students' reflections on their experience performing a capstone project. The impact and influence of each of the model's components should be further researched and measured.
Impact on Society	Moreover, it is very important to prepare the students for employability by including a "real-life" capstone project at the end of their undergraduate studies to prepare them to be valuable in the workforce, even at their start point as juniors.
Future Research	To evaluate the process of employability skills development, a further study can examine students' perceptions prior to the capstone, during, and after to assess the progress and changes. To generalize the results, it would be valuable to investigate whether the findings of this study are consistent across different institutions and disciplines

Keywords	employability skills, capstone projects, soft skills, motivation, information systems studies, student reflections

INTRODUCTION

The importance of soft skills in the Information Systems (IS) industry is no longer an arguable fact and has been broadly discussed both in the industry and the academic literature (Adelakun-Adeyemo, 2021; Jiracheewewong, 2022; St. Louis et al., 2021). The ability of professionals to collaborate, communicate, manage time, negotiate, solve problems, make decisions, and so forth, are sometimes more essential skills than knowledge of new technologies (Acuna et al., 2006; Garousi et al., 2020; Matturro et al., 2019). Soft skills contribute significantly to individual learning, team performance, client relations, and awareness of the business context (Stevens & Norman, 2016). Some employees find soft skills as a more important asset to the first industry position than technical skills (Jones et al., 2018). The list of soft skills defining the human aspects of IS professionals varies and is not fully defined. Following the Matturro et al. (2019) mapping study, the most referred soft skills in the academic literature are communication skills and teamwork skills.

While experienced IS professionals acquire those skills in the field, fresh graduates usually do not have field experience, and there is a gap between the skills learned in undergraduate education and those needed in the industry (Garousi et al., 2020). Nowadays, there is no doubt about the importance of soft skills. However, the academy is still struggling to bring them to undergraduate classes. Some studies raise doubts regarding the ability to train soft skills in the workplace (Stevens & Norman, 2016) and raise the need to develop those skills during undergraduate studies (Aasheim et al., 2009; Jiracheewewong, 2022; St. Louis et al., 2021).

The School of Information Systems at The Academic College of Tel Aviv Yaffo, Israel, prepares highly skilled professionals to address a permanently growing demand of the high-tech industry. The IS School graduates are equipped with a multidisciplinary background combining both technological and management disciplines required to develop and deploy the most advanced information systems and technologies. The studies combine theoretical and practical courses, which are led by industryaccomplished faculty. The aim is to provide a unique environment for applying the acquired knowledge, skills needed in the work field, and practical experience in real-world projects already during the studies.

Students, before graduating, need to participate in two practical work courses constituting the stages of the capstone project of their studies: (1) *Empirical research seminar*, (2) *Analysis and design of a real information system*. To successfully accomplish the capstone project, students must integrate all the knowledge they gained in courses learned in prior years and study some issues by themselves, according to the subject of their project, which is chosen by the students. The requirements for the capstone projects are precisely defined, the processes held in these courses are standard, and all the faculty and mentors act the same way, therefore, preventing possible difficulties as described by previous research (Din et al., 2010; Villamañe et al., 2014). Each stage is managed by two faculty members, who explain the way the course is conducted, teach how to prepare different parts of the project, and monitor during the semester the progression of the teams. Each stage of the capstone project is performed by self-organized teams of three students during one semester. The stages have a Learning Management System (LMS) in which all the materials and explanations needed for performing the project are stored: a precise schedule of the course, the roadmap of the process, forums for questions and answers, and where they submit each deliverable. The structured nature of the capstone project, from the very beginning, prevents students' disappointment (Din et al., 2010).

Despite its significance, few studies have explored students' reflections and the development of soft skills during their final project (e.g., Devi & Abraham, 2020). Thus, this study aims to explore undergraduate IS students' soft skills development through their final project reflections using a case study approach.

The remaining parts of this paper are structured as follows. First, the review of relevant literature is presented in the Theoretical Framework section, followed by the research question. Second, an explanation of the case study on which this research is based is presented. Third, the methodology used is detailed. Fourth, the results of the study, including the facet conceptual framework, are exposed, followed by a discussion and conclusions.

THEORETICAL FRAMEWORK

The capstone project is a critical component of the undergraduate degree program in information systems. This project provides students with an opportunity to apply the knowledge, skills, and techniques acquired throughout their coursework to solve real-world problems. It is an essential learning experience that enables students to demonstrate their proficiency in information systems and their ability to use technology to solve complex problems. The capstone project is one of the ways to develop employability skills using the project-based learning (PBL) methodology.

EMPLOYABILITY SKILLS

Employability is a set of skills that refers to the qualities that make a graduate very suitable for employment (Jiracheewewong, 2022). Employers increasingly look for soft skills in employees which, along with strong technical and subject knowledge, can help their organization continue to develop and prosper. Soft skills refer to all competencies that are not directly related to a specific task but to a broad range of personal and interpersonal skills that are essential for effective communication, collaboration, and problem-solving in the workplace (Cimatti, 2016). Graduates with low employability skills are at risk of not finding work, stagnating in their careers, or losing their jobs to newcomers with high employability skills (Jiracheewewong, 2022). Therefore, academia struggles to find a way to bring those skills to the classes. Two types of courses teaching human aspects are identified:

(a) A primary course – a course whose main goal is to raise awareness of these aspects by defining, simulating, and discussing a model. For example, Hadar et al. (2008) developed a course called *Human Aspects of Software Engineering* where they aimed to teach collaborative software development. For this aim, they used simulations of collaborative software development assignments in which students actively practiced collaboration, followed by reflections in which students analyzed different aspects of their own experience, and ended with group discussion. Kilamo et al. (2012) used a reputation system to support the social aspect of the environment and thus support the learners' collaboration with each other.

(b) A secondary course – a course whose primary goal is to teach technical aspects of the field and the soft aspects are raised as a side effect and discussed by instructors. For example, Weicker (2020) proposes a teaching concept to support students in developing the ability to cooperative problem-solving using a combination of cooperative learning groups in the course of algorithms and data structures. Raibulet and Fontana (2018) described a software engineering course where students developed a software project while simulating collaboration and teamwork activities.

Teamwork

Teamwork is considered one of the essential soft skills required by the industry (Cimatti, 2016). Academia fosters collaboration and teamwork and emphasizes its benefits. For example, Keller et al. (2011) conducted a qualitative study aimed at investigating whether information systems students undertaking a team-based capstone had enhanced their employability skills. This study reports on improvements in the ability to work collaboratively in teams (Keller et al., 2011). Sherman et al. (2022) reported on a study aimed to explore the specific characteristics of students' teamwork in a practical course delivered in an industrial setting. In this qualitative study, students reported on communication, coordination, and member contributions balance as the main factors of project success. Those factors are part of the Teamwork Quality (TWQ) model proposed by Hoegl and Gemuenden (2001). This model aims to capture the collaboration within the teams and is constructed from six facets: communication, coordination, member contributions balance, mutual support, effort, and cohesion. The authors show that the model links between the project's success as measured by team performance (effectiveness and efficiency) and team members' personal success (satisfaction and learning). This model was further used while qualitatively studying students' reflections (Hoegl & Gemuenden, 2001).

Time managing – Planning and Organizing

Time management is an essential employability skill that enables individuals to achieve their goals and be successful in their careers. Time management skills refer to the ability to prioritize, plan, and organize one's time effectively to achieve specific goals and can be identified as clusters of behavioral skills that are important in the organization of study and course load (Lay & Schouwenburg, 1993). Cottrell (2019) argues that in today's fast-paced working environment, individuals who possess effective time management skills are better equipped to cope with the demands of their jobs, stay on top of their tasks, and accomplish their objectives in a timely and efficient manner. Any lack of these skills makes a graduate a poor job candidate and a worse employee (Osmani et al., 2019). During capstone projects, students must plan their work and manage themselves throughout the semester towards completing their work on time and with quality results (Auvinen et al., 2020). Because self-management is so interdependent with employability skills such as teamwork and inter-communication, most students performing capstone projects did not explicitly report improvements in this area (Keller et al., 2011). However, efficient time management focused on the required course deliverables, as well as group cohesion, resulted in the most significant outcomes (Ball et al., 2020).

Inter-Communication

Inter-communication is communication with project stakeholders who are not part of the project team. The inter-communication is a necessary skill for dealing with coworkers and communicating with clients and other stakeholders at work and elsewhere (Idkhan et al., 2021; Kleckner & Butz, 2022). Students collaborate closely with their assigned supervisors, who guide them on a learning path throughout their project work (Adelakun-Adeyemo, 2021). The team mentor in project-based learning plays a significant role in the quality of the overall outcome (Adelakun-Adeyemo, 2021), facilitates collaboration within the team (Sherman et al., 2022), and mentors students to develop professional and soft skills (Bastarrica et al., 2017; Nghia, 2019).

Knowledge

Capstone projects provide an opportunity for undergraduate IS students to showcase their knowledge and skills in a real-world setting. In their capstone projects, students must integrate their prior knowledge, new knowledge, and skills to develop a solution to a complex problem. Knowledge can be conceptualized as comprising three facets: prior knowledge, new knowledge, and knowledge integration.

Prior knowledge refers to the knowledge that students bring with them to the capstone project. This knowledge can come from previous coursework, work experience, or other sources. As shown by Greene et al. (2008), high prior knowledge students could demonstrate more self-reflective and monitoring behaviors than lower prior knowledge students. Additionally, Bernacki et al. (2012) indicated that students with high prior knowledge could usually use a more active learning approach while those with low prior knowledge passively followed the instructions. Sung et al. (2016) found that prior knowledge was a key factor in students' learning performance.

New knowledge refers to the knowledge that students acquire during the capstone project. This knowledge can come from a variety of sources, including research, collaboration with peers, and feedback from instructors. New knowledge is a critical aspect of capstone projects. Holdsworth et al. (2009) noted that capstone projects provided an opportunity for students to develop new knowledge and skills that they could apply in their future careers.

Knowledge integration refers to the process by which students combine their prior knowledge and new knowledge to create a comprehensive understanding of the topic. According to Steiger (2009), knowledge integration is a crucial aspect of capstone projects, and such knowledge integration is critical to graduating IS students since they will be expected to apply their specialized knowledge to a wide variety of business problems. Similarly, Mehta and Mehta (2018) indicated that both learning and performance-prove goal orientations positively influenced team knowledge integration, and knowledge integration impacted both objective and subjective dimensions of team effectiveness.

Project-Based Learning (PBL)

Project-Based Learning (PBL) is a student-centered teaching methodology that is increasingly being adopted in higher education as it has been found to develop and enhance students' engagement, critical thinking skills, problem-solving skills, and team collaboration skills (e.g., Krajcik & Shin, 2014). The approach involves students working on real-world problems that require them to apply their knowledge and skills to find solutions as a basis for learning (Hmelo-Silver et al., 2007). PBL fosters active learning, which was found to increase students' engagement and academic achievement in STEM-related courses (e.g., Aji & Khan, 2019; Ralph, 2016).

Guo et al. (2020) conducted a meta-analysis of 76 studies on PBL in undergraduate education. The authors found that learners' knowledge, strategies, and skills were frequently measured. These learning outcomes received much attention due to employers' reports that basic knowledge and skills are essential for students' readiness to work. Several studies have shown that PBL is an effective teaching methodology for information systems education and has been used to enhance student learning outcomes in various courses, including research, analysis, and design of information systems. Kardoyo et al. (2019) used PBL to teach management information systems courses to graduate students. The study found that PBL improved students' ability to apply project management concepts and tools in real-world situations, leading to better critical and creative thinking skills.

As part of a research seminar leading to the analysis and design of information systems, students are required to tackle a new concept, use prior knowledge, acquire new one, and integrate both while approaching different perspectives (Steiger, 2009). Zen and Ariani (2022) investigated the impact of PBL on the development of information literacy skills in undergraduate students. The authors found that PBL was an effective method for developing students' information literacy skills, including the ability to locate, evaluate, and use information effectively.

PBL has been found to foster the development of key skills that are highly valued by employers, such as teamwork, communication, and project management (e.g., St. Louis et al., 2021). PBL enhances student engagement by providing students with opportunities to work on real-world contexts and problems to learn from (Jurdak, 2016) and is relevant to their future careers (LaForce et al., 2017). Woodward et al. (2010) found that PBL was successful in teaching information systems management by providing students with opportunities to practice these skills in a real-world context. This approach allows students to see the practical application of what they are learning, leading to higher motivation and engagement.

In the context of information systems, students often work in teams to solve complex problems, and PBL provides an excellent opportunity for students to develop teamwork and collaboration skills. This approach prepares students for the collaborative nature of the workplace, where teamwork is essential for project success (Rajabzadeh, et al., 2022).

PBL promotes and enhances students' problem-solving skills and encourages them to think critically about the material (Loyens et al., 2023). According to Bell and Kozlowski (2008), PBL requires students to use higher-order thinking skills, including analysis, synthesis, and evaluation. These skills are essential in the research, analysis, and design of information systems, where students need to analyze complex problems and develop innovative solutions. PBL has also been found to improve student engagement and motivation. In a study by Hwang and Kim (2006), students who participated in a PBL course reported higher levels of engagement and motivation compared to those who participated in a traditional lecture-based course. This is likely because PBL allows students to take ownership of their learning and work collaboratively with their peers.$

In information systems settings, Hussein (2021) conducted a study to explore the effectiveness of PBL in teaching information systems to undergraduate students. The author found that PBL was an effective method for teaching information systems concepts and skills, as it helped students to develop problem-solving, critical thinking, and teamwork skills. The study also found that PBL increased students' motivation and engagement in the learning process. In another research by Naqvi et al. (2019), it was found that PBL significantly improved students' academic performance, and students who participated in PBL reported higher levels of satisfaction with the course. The study also found that PBL helped to develop students' communication, collaboration, and leadership skills.

While PBL has many benefits, there are also challenges associated with its implementation. One of the biggest challenges is the amount of time and resources required to design and implement effective PBL activities (Aldabbus, 2018). In addition, some instructors may lack experience or training in PBL, which can make it difficult for them to effectively design and facilitate PBL activities (Albanese & Mitchell, 1993). Another challenge is the difficulty in assessing students' learning in PBL. PBL activities are often complex and multifaceted, which can make it challenging to evaluate students' learning outcomes (Guo et al., 2020). Additionally, students may have different roles and responsibilities within a PBL group, which can make it difficult to assess individual student learning (Boss, 2012). One way to assess the effectiveness of PBL is to use qualitative tools that can capture students' reflections and experiences.

STUDENTS' REFLECTIONS

Reflection is a process of thinking deeply about one's experiences, analyzing them, and making connections to prior knowledge. Reflective practices can be defined as "the process of internally examining and exploring an issue of concern, triggered by an experience, which creates and clarifies meaning in terms of self, and which results in a changed conceptual perspective" (Boud et al., 2013, p. 19). In PBL, reflection is essential for students to make connections between theory and practice and to develop a deeper understanding of the learning outcomes (e.g., Kolb, 1984; Savery, 2015). Reflection also helps students to identify areas where they need to improve and to set goals for future learning.

Reflective practices can help students to identify their own learning needs and to develop their critical thinking skills (Schön, 1984), to make connections between theory and practice, develop their problem-solving skills, and reflect on their own learning process (Hmelo-Silver et al., 2007; Savery & Duffy, 1995). Saltiel (2009) noted that "Reflective practice engages with the messiness, the unpredictability, the uncertainty of practice, focusing not on abstract theory but on the real experiences of practitioners and the skills they develop as they try to make sense of those experiences. It emphasizes the expertise – the skill and artistry."

Reflective practices have been used to support the development of students' communication skills (Karnieli-Miller, 2020), teamwork skills (Rania et al., 2021), and critical thinking skills (Mills et al., 2006). Reflective practices have been suggested as a way to support the development of students' problem-solving skills in the context of PBL (Hmelo-Silver et al., 2007). Reflective practices have also been used to support the development of students' meta-cognitive skills, which involve the ability to monitor and regulate one's own learning process (Savery & Duffy, 1995). Reflective practices can take many forms, including journaling, group discussions, and individual reflections (Boud et al., 2013). A reflection is a valuable tool for assessing student knowledge, skills, and motivation, as it allows educators to gain insight into the students' learning process, their understanding of the subject matter, and their experiences of the learning environment (Schön, 1984). Student reflections are a valuable qualitative research tool that can provide rich insights into students' learning experiences and outcomes in information. Specifically, student reflections can be used to explore the following areas:

1. Perceptions of technology: student reflections can reveal students' perceptions of technology, including their attitudes towards specific technologies, their experiences using them, and their perceived benefits and challenges. For example, in a study by Gallegos et al. (2017), student reflections were used to explore their experiences using a gamified learning platform, revealing their positive attitudes toward the platform's interactive features and the benefits of gamification for learning.

2. Learning outcomes: student reflections can provide insights into the effectiveness of teaching methods and strategies, as well as the impact of learning activities on students' knowledge, skills, and attitudes. For example, in a study by Jaeger-Helton et al. (2019), student reflections were used to evaluate the effectiveness of a collaborative project-based learning approach in developing students' teamwork, communication, and skills. Student's reflections focused on specific technical skills, along with project management; when asked what they learned about themselves, they mentioned communication, teamwork, and personal development skills such as time management, perseverance, and tolerance for ambiguity.

3. Personal development: student reflections can also reveal students' personal growth and development, including their self-awareness, values, and goals. For example, in a study by Tiernan (2021), student reflections were used to explore their perceptions of their own digital literacy skills.

Unstructured student reflections refer to a process in which students are given the freedom to reflect on their learning experiences in an open-ended manner without any specific prompts or guidelines (Moon, 2013). Several studies have explored the use of unstructured student reflection as a research tool for assessing student learning. For example, Minott (2008) examined the use of unstructured written reflections and found that unstructured reflections provided valuable insight into student thinking, as students were able to express their ideas and beliefs in a non-judgmental environment. The use of unstructured reflections is also useful for assessing student motivation and engagement, as students can express their feelings about their learning experiences (Wurdinger & Carlson, 2009). Denton (2018), who incorporated unstructured written reflections into an introductory statistics course, pointed out a major challenge in this method, for researchers and students alike. Some students may find the writing process to be particularly burdensome.

RESEARCH QUESTION

This study explores undergraduate IS students' soft skills development while performing their final capstone project during their academic studies. One overarching research question guided this study:

> **RQ**: What are the facets that the capstone project exposed the IS students to, according to their reflections?

THE CASE STUDY

The capstone project is an integral component of undergraduate education in The Information Systems (IS) School at The Academic College of Tel Aviv Yaffo, Israel. The capstone allows students to apply theoretical knowledge to practical problem-solving in two parts: (1) *Empirical research seminar*, and (2) *Analysis and design of a real information system*. The students need to demonstrate the integration of all the knowledge they gained in courses learned in prior years and study some issues by themselves, according to the subject of their project.

The *empirical research seminar* consists of a "mini-thesis". The learning process begins by choosing a topic, which the students are curious about, and is relevant to the field of information systems or cybersecurity, according to the specialty they study. They formulate research questions, define the research process, collect data, and analyze the results, according to the principles of the scientific approach.

The *analysis and design of a real information system*, which the students choose, include learning the current situation of the system/processes, determining the goals, objectives, and scope of the new system, identification of stakeholders and gathering user requirements, defining the new processes, data, and technology to be used, and finally, preparing a mock-up of the new system.

There are five meetings during the semester for all the students participating in each course, arranged by the academic teachers, thus, supporting the students and avoiding students' feelings as 'under-supported, stressed, or isolated' during the process (Villamañe et al., 2014). The process carried out in the courses has several steps:

1. The first meeting, in which the students learn about the essence of the capstone project and the proposals they must write.
2. The project subject and scope are proposed by the students according to their interests. After the first meeting, each team meets with the academic teacher to discuss the project proposal, redefine it if needed, and is finally approved by the teacher.
3. For each team whose proposal was approved, a professional mentor, from industry or academy, is assigned to guide them during the semester. This mentor is selected according to the subject matter of the project to ensure relevance. The work must be done autonomously by the students.

4. In the second meeting, the students learn how to write the work plan for the project. This plan includes the definition of the tasks to be performed, a Gantt, including the distribution of work between the teammates, and risk analysis, with a plan to mitigate the risks. The work plan of each team is approved by their mentor prior to starting the work.
5. Before the third meeting, the students need to handle a status review. During the meeting, different aspects, according to the progress of the works, are explained.
6. Before the fourth meeting, the students need to handle a second report on their progress status. In this meeting, the students learn how to handle the written report and all outcomes of the project and how to prepare the oral presentation, which will be accompanied by a poster they design.
7. At the end of the semester, the students submit all their outcomes to the mentors and academic teachers. The mentors evaluate the outcomes and the teams' process during the semester according to a standard indicator. This report is given to the academic teachers who grade the work.
8. Finally, the students present their work to the academic teachers, mentors, faculty, guests, and other students, in a festive ending event, where the Top-10 projects are nominated (Kar et al., 2013).

After completing the work, and before the presentations and grading, they must handle a written personal reflection. Bastarrica et al. (2017), according to their research, claim that the perceived relative value of the technical challenge drops by the end of the capstone, and students are already technically prepared and able to face real-world projects, and they acknowledge that soft skills are also determinant for the success of the projects. Therefore, in this study, the students were asked to reflect after finishing the capstone. The students had no guidance or format to write the reflections. Each student could write whatever he or she wanted or felt. The students knew that the reflections were not part of the grading.

RESEARCH METHODOLOGY

A singular case study (Thomas, 2011) was conducted to examine the IS students' development of skills and to gain a better understanding of students' perceptions and attitudes during their final project. This methodology, according to Stake (1995), is a "study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (p. xi). The characteristics of a case study are Holistic (considering the interrelationship between the phenomenon and its contexts); Empirical (basing the study on their observations in the field); Interpretive (resting upon their intuition and seeing research basically as a researcher-subject interaction); and Emphatic (reflecting the vicarious experiences of the subjects in an emic perspective) (Yazan, 2015).

Due to the exploratory nature of this research, a mixed methods approach was employed (Venkatesh et al., 2016) using qualitative and quantitative approaches methods. The process of the data analysis is graphically displayed in Figure 1.

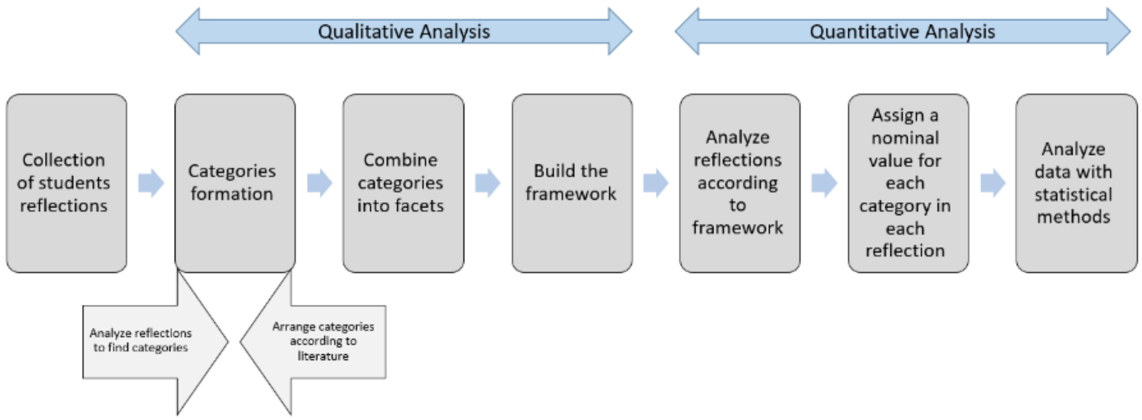

Figure 1. Graphical description of the process conducted

Qualitative data analysis

The study's data was collected from unstructured students' reflections. Unstructured students' reflections refer to a process in which students are encouraged to explore and express their thoughts, feelings, and experiences related to a learning activity or an event without any specific guidance or structure. According to Henderson et al. (2017), an unstructured reflection involves "a process of critical self-awareness in which the learner seeks to develop a deeper understanding of his or her own experiences, attitudes, and beliefs, often through open-ended and unstructured dialogue with others or through reflective writing" (p. 1571).

A qualitative approach was applied to understand the phenomena via empirical observations of human behavior and experience (Bogdan & Biklen, 2007). The students' unstructured reflections were analyzed following the principles of grounded analysis (Strauss & Corbin, 1998). The data analysis was an iterative exploratory process of going back and forth between the empirical materials and literature, assessing and interpreting theoretical constructs with the analyzed data, and using Microsoft Word® and Excel® to code, categorize and identify themes in the empirical material. The data were categorized in terms of content, using categories derived from the analysis.

A framework was developed derived from the data itself that captures the analytically significant features of the data. Initially, the framework included a list of categories, which was organized according to higher-order code categories, accompanied by their definitions. The framework constitutes the analytic instrument with which the raw data was then reduced, classified, and synthesized (Gaskell, 2000). Each step of the categorizing method was done by one researcher and then was discussed with the other researchers until arriving at an agreement in a joint session (a consensus approach), changing their roles from step to step. This was done to maintain a continuous dialogue between researchers and consistency of the coding (Walther et al., 2008) and to establish inter-rater reliability (IRR) to ensure the trustworthiness of the study (Miles & Huberman, 1994). The conceptual framework proposed in this study does not include categories that were not substantive enough to be supported by sufficient quotes (e.g., the category "technical issues", which had only three quotes, was omitted). TWQ (Hoegl & Gemuenden, 2001) framework was utilized as a base for the conceptual framework for teamwork, which consists of six facets, including communication, coordination, member contributions balance, mutual support, effort, and cohesion. The qualitative analysis resulted in the construction of a conceptual framework with categories and facets.

Quantitative data analysis

The quantitative analysis involved a systematic process of coding and analyzing qualitative data. The coding scheme involved two bottom-up phases. (1) The data was first coded using the basic categories derived from the qualitative data analysis to code the occurrences of the categories in the reflection as positive, negative, or not found in the text. Each was assigned a nominal value of -1, 0, or 1 to the category to represent the negative sentiment (-1), absence sentiment (0), or positive sentiment (1) of the category. This process of coding categorical data with numerical values is a common technique used in the quantitative analysis of qualitative data to enable analyzing the data using statistical methods (Guest et al., 2012). This coding process was based on a grounded theory approach, which emphasizes the importance of allowing the data to speak for itself (Charmaz, 2014). (2) After the initial coding was complete, to create a more comprehensive analysis, the categories were combined into the facets found, by summing the categories related to the corresponding facet, thus creating variables that are considered ordinal. For instance, the facet "Knowledge" was created by combining three categories: prior knowledge, new knowledge, and integrating knowledge, each one of which was coded as a nominal variable (-1, 0, 1). The resulting ordinal variable for the facet was their sum, which ranged from -3 to 3, ranking the report of knowledge in the reflections. The new ordinal variable for the facet "Teamwork" was created by combining the five categories of the TWQ model (out of the original six), each one of which was coded as a nominal variable (-1, 0, 1). The resulting ordinal variable for the facet was their sum, which ranged from -5 to 5, ranking the report of teamwork in the reflections. This technique of combining related categories to create composite variables is widely used in qualitative research (Bryman, 2016). One study that highlights the use of nominal and ordinal variables in qualitative data analysis is by Buckingham Shum et al. (2016), who used a similar coding scheme to analyze the reflections of medical students. They found that using nominal and ordinal variables allowed for a more detailed and precise analysis of the data, which in turn led to a better understanding of the students' learning experiences.

Overall, the use of quantitative coding in the analysis of qualitative data allowed for a rigorous and systematic approach to identifying patterns and themes in the reflections. The combination of nominal and ordinal variables allowed for a more nuanced understanding of the data, and the use of grounded theory ensured that the analysis was firmly rooted in the data itself.

CASE DESCRIPTION AND DATA COLLECTION

Data was collected from 2nd and 3rd year IS students in a higher education institution, performing their final project. This study is based on an unstructured personal reflection given at the end of the capstone project (two stages: *Empirical research seminar* and *Analysis and design of a real information system*). The reflection was not graded as part of the final course's grade. The capstone project was performed between February 2022 and June 2022. The data was collected from four final project cohorts (seminar A, seminar B, seminar C, and Analysis and Design A) containing 156 reflections from 170 students in 57 teams (Table 1). The cohorts of seminars were in parallel and divided randomly.

Table 1. Study participants

Course Cohort	N Participants	N Reflections
Seminar A	38 students 13 teams	30 reflections
Seminar B	40 students 13 teams	39 reflections
Seminar C	48 students 16 teams	45 reflections
Analysis and design A	44 students 15 teams	42 reflections
Total	**170 students** **57 teams**	**156 reflections**

The quotes in this study are translations of the original excerpts, staying as close as possible to the original expressions and idiomatic nuances. To secure anonymity and confidentiality, the respondents have been anonymized.

RESULTS

Among the 170 students participating in the courses, 156 completed their unstructured reflections at the end of the capstone process and after submitting their final academic product. The qualitative findings of the mixed methods approach identified three main factors in the students' reflections: knowledge (prior knowledge, new knowledge, and knowledge integration), skills (teamwork, time management, and inter-communication), and motivation (personal, social, and constraint). According to this framework, three recurring themes were identified regarding knowledge, three recurring themes regarding skills, and three recurring themes regarding motivation. The facets conceptual framework based on all the categories and facets identified is presented below (Figure 2), followed, first, by a description of each facet and examples from students' reflections; and next, by the quantitative findings of the mixed methods approach based on the facets conceptual framework identified. The distribution of the facets conceptual framework was explored (N=156) and the differences between the two stages of the capstone: Empirical research seminar (N=114) and analysis and design of real information systems (N=42) regarding the facets conceptual framework.

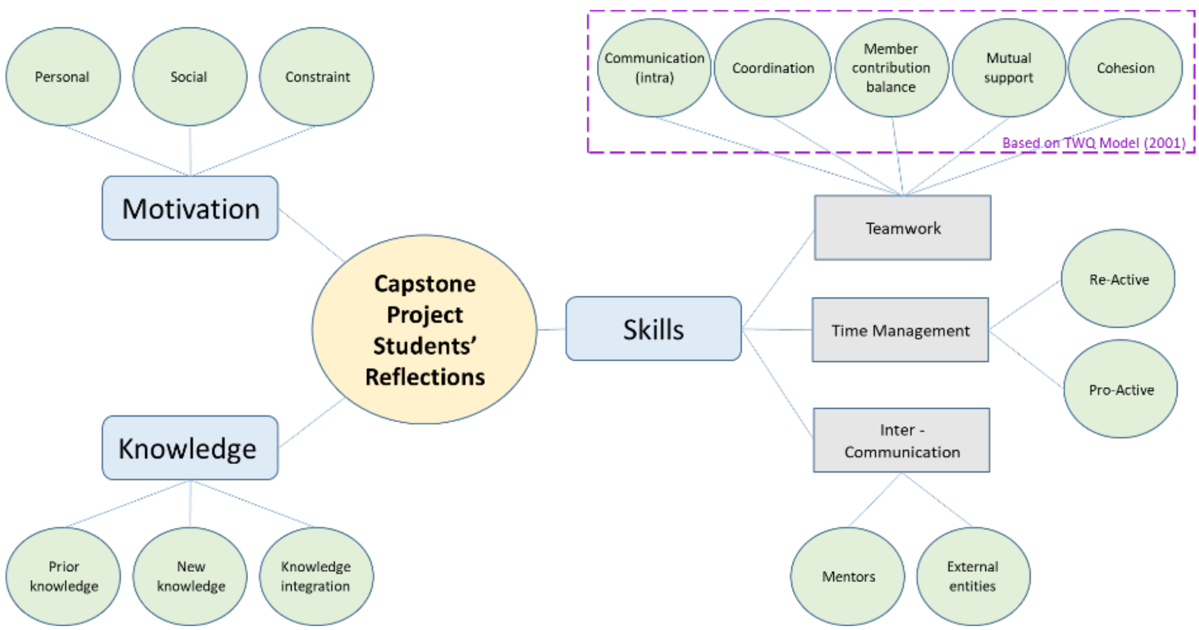

Figure 2. The facets conceptual framework

MOTIVATION

Choosing a topic for a final capstone project is a complex task that lasts for about two weeks at the beginning of the semester, during which students change and refine their proposal until the final approval is received. On the one hand, all project requirements must be met, and on the other hand, students desire to do work in the field of content close to them. Behind this choice, there are many constraints, such as project scope requirements, team preferences, and feasibility. During the data analysis, three types of motivation were identified for the capstone project choice: personal motivation, social motivation, and constraint. Table 2 summarizes these categories, followed by explanations and examples from students' reflections.

Table 2. Motivation factor data analysis

Personal Motivation	Students have a personal motivation for choosing the subject. It can be an early acquaintance with a field, a desire to be exposed to a new field, or a goal to deepen some topic.	*"Choosing the subject of the seminar was very significant for me because I wanted to carry out research on a topic relevant to everyday life and this research may be of benefit to the individual."* *"We chose to do the project about a gym. In my daily routine, I like to exercise and spend at least three times a week at the gym, on which we performed the work. When I started thinking about the system, I came up with the idea of a full package that a gym needs."*
Social Motivation	Choosing a topic due to the potential contribution to the community.	*"The issue is important to the professional knowledge community."* *"When we approached the project, I tried to find an idea that would be interesting to implement, and also of added value to the company."*
Constraint	Choosing a subject due to external constraints (sometimes of their teammates) and not a free choice.	*"The subject we wanted was already chosen, so we chose something else."*

When examining the motivation facet and its three aspects, personal, social, and constraint, it was found that 46.49% at the empirical research seminar stage vs. 55.81% at the analysis and design stage reported having a personal or social motivation for choosing the selected topic and only 7.89% at the empirical research seminar stage vs. 6.98% at the analysis and design stage reported have both (Figure 3). When examining each aspect separately, there is a significant difference between the stage of the capstone and social motivation ($\chi^2 = 11$, df $= 1$, $p < 0.01$). No differences were found ($\chi^2 = 5.19$, df $= 2$, $p > 0.05$) when reporting personal motivation between stages. Students from the analysis and design stage of the capstone reported having chosen topics out of social motivation more than the students in the empirical research seminar. When examining the aspect of constraint, there is a significant difference between the stage of the capstone and a constraint ($\chi^2 = 4.3$, df $= 1$, $p < 0.05$). Students from the analysis and design stage of the capstone reported having fewer constraints than the students in the empirical research seminar.

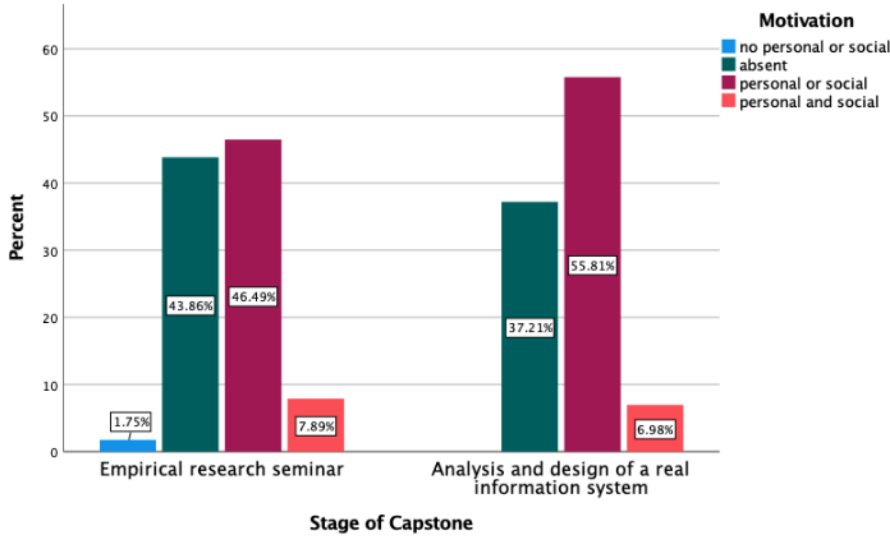

Figure 3. Clustered bar percent of the stage of the capstone by motivation (N=156)

Knowledge

While working on a final capstone project, the students are not only required to apply the knowledge they have gained during their undergraduate studies but also to study new topics on their own. In the reflections, three categories of learning were identified: prior knowledge – review of materials learned in previous courses (e.g., statistics, research methods, project management, system analysis, and design, etc.), learning new content, and integrating knowledge. Table 3 summarizes these categories, followed by explanations and examples from students' reflections.

Table 3. Knowledge factor data analysis

Prior knowledge	To refresh their memory, students returned to relevant topics learned in previous courses and reviewed the materials.	*"I needed to review materials we have learned."*
Learning new Knowledge (content and process)	Refers to declarative knowledge (facts) and procedural knowledge (process). Students learned by themselves new topics and tools they needed from the internet or other sources and from relevant literature references.	*"The background and the tools for performing various statistical tests, since we did not perform data analysis at the level required of us in any of the statistics courses before. Despite this, we were able to overcome these difficulties by reading from several different sources about different statistical tools and how to use them, in addition, I learned to work with the SPSS software."*
Knowledge integration	Knowledge integration between and among the courses they studied in the past and with the new knowledge they gained	*"I learned a lot of new things about the field and its connection to the field of information security that we studied in the courses."*

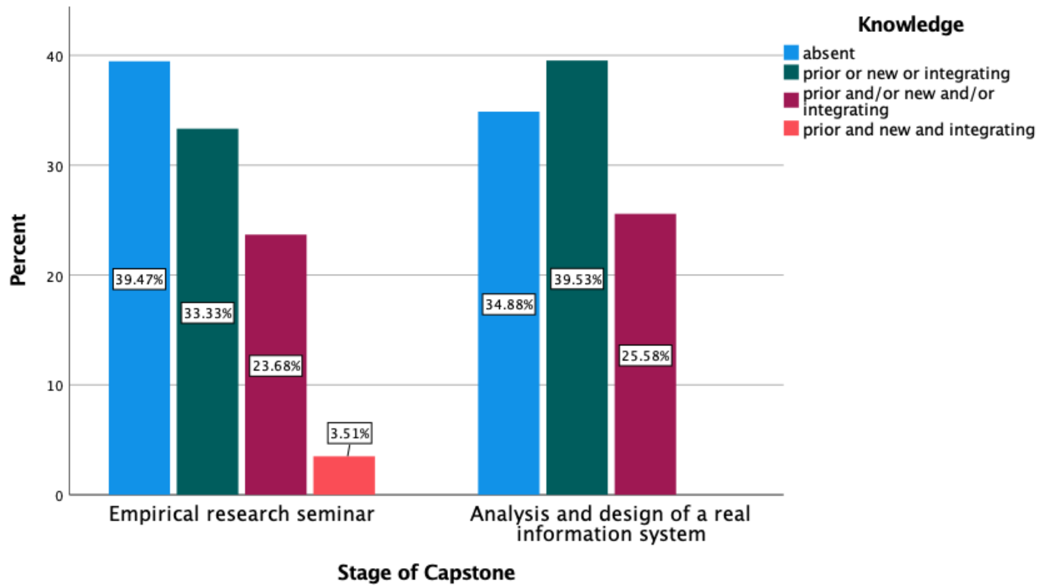

Figure 4. Clustered bar percent of the stage of the capstone by knowledge (N=156)

When examining the knowledge facet and its three aspects, prior knowledge, new knowledge, and knowledge integration, it was found that 33.33% at the empirical research seminar stage vs. 34.88% at the analysis and design stage reported using prior knowledge or learning new knowledge or integrating knowledge, and only 3.51% at the empirical research seminar stage vs. 25.58% at the analysis and design stage reported to use prior knowledge, learn new one and integrate both (Figure 4). When examining each aspect separately, there is a significant difference between the stage of the capstone and knowledge integration ($\chi^2 = 9.55$, $df = 2$, $p < 0.01$). On both aspects of prior knowledge and new knowledge, no differences were found ($\chi^2 = 0.95$, $df = 1$, $p > 0.05$; $\chi^2 = 4.5$, $df = 2$, $p > 0.05$ respectively). Students from the analysis and design stage of the capstone report about integrating knowledge more than the students in the empirical research seminar.

SKILLS

Teamwork

The teamwork quality model, known as the TWQ model (Hoegl & Gemuenden, 2001), contains six facets, including communication, coordination, member contributions balance, mutual support, effort, and cohesion. During data analysis, five out of six facets were identified. Table 4 summarizes these facets, explanations, and examples from students' reflections.

Table 4. TWQ facets data analysis

TWQ facet	Explanation (Hoegl & Gemuenden, 2001)	Example
Communication (intra)	The means for information exchange among team members (intra-communication). "The quality of communication within a team can be described in terms of the frequency, formalization, structure, and openness of the information exchange" (p. 347).	*"We made all the choices together following a brainstorming session. All the decisions were carried out in a collaborative manner and everything was agreed upon by everyone - client, project, and content distribution."* *"The cooperation of the team members was perfect and we integrated perfectly both with each other and with our mentor, whether it was in group discussions, consultations, or whether it was in individual conversations and discussions about how to perform the tasks."* *"We held many group meetings on Zoom and face-to-face to discuss the research topic and the structure and content of the final submission."*
Coordination	"Coordination means that the teams have to develop and agree upon a common task-related goal structure that has sufficiently clear sub-goals for each team member, free of gaps and overlaps" (p. 347).	*"We held joint discussion sessions and occasionally split up to optimize our times. In my opinion, the group worked very well, we focused our attention without any distractions, we set up the goals for each meeting and finally we integrated and read the research together, and corrected notes until the final submission was formulated."*
Member contributions balance	"It is considered essential to TWQ that contributions to the team task are balanced with respect to each member's specific knowledge and experience" (p. 347).	*"The distribution of the workload was relatively equal among the team members."* *"I think that as a group we worked in collaboration, we identify what are the strengths of each of the team members and we knew how to take advantage of that."* *"The distribution of workloads was divided evenly and harmoniously when each team member expressed his/her opinions."*
Mutual support	"Team members working on a common goal should display mutual respect, grant assistance when needed, and develop other team members' ideas and contributions rather than trying to outdo each other" (p. 348).	*"During the research, there were occasional disagreements between the team members, which led to deepening the theoretical background and statistical analyses. The differences of opinion challenged us to explore and get a different perspective. Through the ability to have a conversation we were able to reach a consensus and finally reach a finished product."* *"In addition, the collaboration between us was excellent, and sometimes group work and individual work was done according to loads of each member of the group."*

TWQ facet	Explanation (Hoegl & Gemuenden, 2001)	Example
Cohesion	"Refers to the degree to which team members desire to remain on the team" (p. 348).	*"I wouldn't have done better with others."* *"I enjoyed working with the team members and the dynamics improved over time as we progressed towards the final product."*

As explained in the data analysis section, the new ordinal variable "Teamwork" was created by combining the five categories of the TWQ model (out of the original six), each one of which was coded as a nominal variable (-1, 0, 1). The resulting ordinal variable for the facet was their sum, which ranged from -5 to 5, ranking the report of teamwork in the reflections. When examining the teamwork facet, it was found that 52.86% of the students (N=156) reported to had more than three elements of teamwork (Figure 5). When examining the two stages of the capstone, there is no difference between the stage of the capstone and the teamwork ($t = .322$, $df = 155$, $p > 0.05$). Specifically, students from both stages of the capstone (the seminar: M=2.33, SD=1.76; the analysis and design: M=2.21, SD=2.06) have similar teamwork scores.

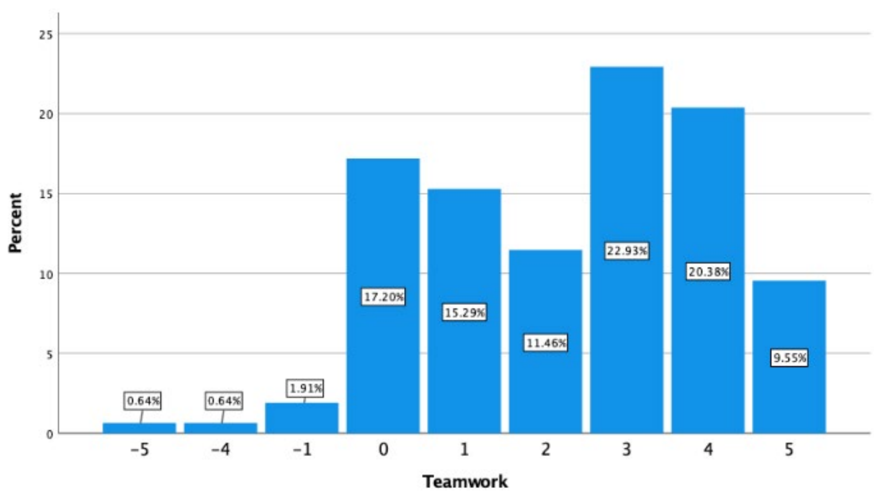

Figure 5. Distribution of teamwork facet (N=156)

Inter-Communication

Communication emerged from the data analysis in several contexts, in the context of communication in teamwork, mentioned as intra-communication (in Table 4), and in the context of other entities. Inter-communication refers to the students' communication with stakeholders. These stakeholders include project mentors, the course coordinators, and real clients (for the analysis and design-based capstone) or research samples (for a research-based capstone). Table 5 summarizes these categories, followed by explanations and examples from students' reflections.

Table 5. Inter-communication factor data analysis

Inter-Communication with mentors	Students referred to the help, constructive feedback, and support they received from the mentors.	*"He contributed a lot to us with the help of his knowledge and experience."* *"We received positive and negative feedback, an in-depth and instructive discussion."*
Inter-communication with external entities	Students referred to their communication with external entities such as experts, project clients, and/or the research participants.	*"We received cooperation from people I don't know."* *"Reached senior officials in the industry."*

When examining the inter-communication facet, it was found that 38.6% at the empirical research seminar stage vs. 51.16% at the analysis and design stage reported using communication with mentors or external entities, while 6.14% at the empirical research seminar stage vs. 30.23% at the analysis and design stage reported doing both (Figure 6). There is a significant difference between the stage of the capstone and the inter-communication ($\chi^2 = 24.67$, df = 2, $p < 0.01$). Students from the analysis and design stage of the capstone report to use more inter-communication with mentors and external entities.

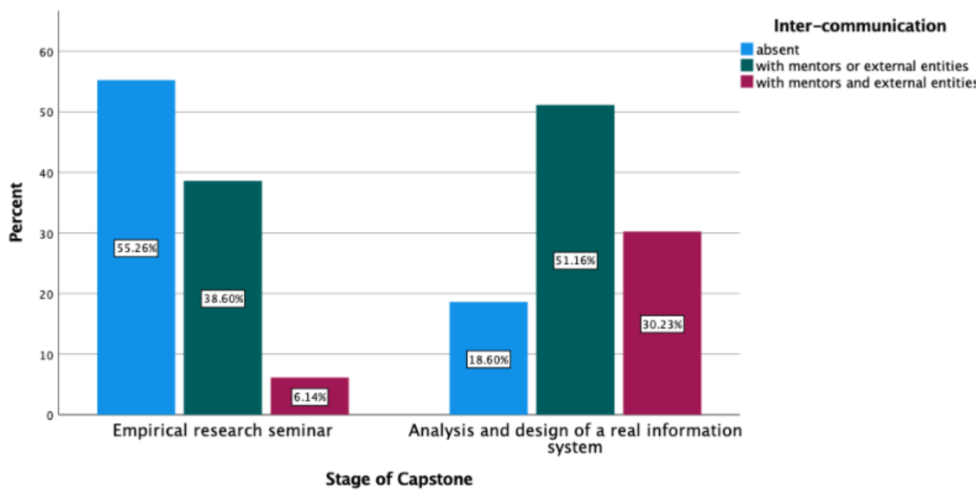

Figure 6. Clustered bar percent of the stage of the capstone by inter-communication (N=156)

Time Management

A final capstone project is carried out according to a strict schedule. The first meeting with the students takes place in the first week of the semester, and the submission of the final product takes place in the week before the end of the semester. To meet all the milestones defined in the final project and to practice the preparation of work plans as they studied in previous project-management courses, the students must plan their time in an optimal way. To meet the deadline, it is not possible to deviate from this schedule. In their reflections, the students referred to time management in two aspects: proactively while they reflect on the importance of planning time in advance, and reactively while they reflect on the problems they experienced with time management. Table 6 summarizes these categories, followed by explanations and examples from students' reflections.

Table 6. Time management factor data analysis

Pro-active	Students reported that planning their work in advance was an important factor that prevented them from reactive time management and procrastination.	*"A work plan that prevented procrastination."* *"Everything was planned in a realistic and good way - including 'Buffers' for unexpected issues and schedule changes and allowed us to be flexible without affecting the delivery times."*
Re-active	Even though students planned their work, unexpected tasks impacted the pace of the project's progress. In those cases, students acted proactively. In some cases, students reflected that they worked under pressure and chaos but mostly managed to meet the set goals.	*"It should be noted that despite the planning and anticipation, personal constraints affected the dates of the meetings and the progress of the project, which in my opinion, is an integral part since we will never work on one project or assignment and therefore need to learn how to prioritize and divide the time (in our case between different assignments and courses)."* *"I felt that our weak point while working on the project was time management. I felt that many times we could have managed the time more efficiently and correctly."* *"I learned how to distribute loads and how to optimize my work processes and those of the other team members."*

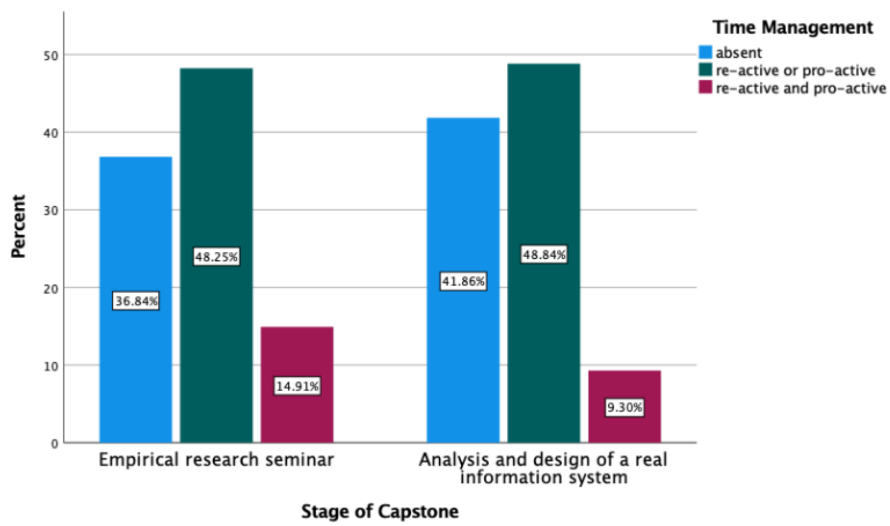

Figure 7. Clustered bar percent of the stage of the capstone by re-active time management (N=156)

When examining the time management facet and its two aspects, re-active and pro-active, it was found that 48.25% at the empirical research seminar stage vs. 48.84% at the analysis and design stage reported being re-active or pro-active in time management and only 14.91% at the empirical research seminar stage vs. 9.3% at the analysis and design stage reported to do both (Figure 7). There is no difference between the stage of the capstone and both aspects of time management, re-active and pro-active ($\chi^2 = .19$, $df = 1$, $p > 0.05$; $\chi^2 = 0.16$, $df = 1$, $p > 0.05$ respectively). Specifically, students from both stages of the capstone manage their time in a similar manner.

DISCUSSION

The findings of this study contribute to the understanding of the facets and factors that students experienced during a capstone project in Information System undergraduate studies, based on 156 reflections out of 170 students in four different courses participating in the capstone project during the specific semester. The main aim of the capstone project is to provide students with the opportunity to apply theoretical knowledge to practical problem-solving. Employability and soft skills were not explicitly defined or graded. The reflections were unstructured, and the students did not receive any specific instructions on what to refer to and how to write them. However, students learned in previous courses the meaning and essence of reflecting. Students could have referred to any aspects of their work. Nevertheless, they referred to the soft aspects and employability skills.

A mixed methodology was employed to explore the students' reflections. The qualitative analysis showed that students' reflections on their motivation, knowledge, and skills resembled the importance of those facets in the process they underwent. The quantitative analysis provided further insights into the differences between the two stages of the capstone project. Accordingly, a facets conceptual framework was constructed (Figure 2), which identified three main factors in the students' reflections: motivation, knowledge, and skills. The motivation facet is composed of three factors: personal motivation, social motivation, and constraints in choosing a topic. The knowledge facet is composed of three factors: prior knowledge, new knowledge gained during the project, and knowledge integration. The skills facet is composed of three factors: teamwork, time management, and inter-communication, and each of these factors is further decomposed.

Motivation is essential to perform a capstone project, which is very demanding work performed in a team. Students' motivation can be influenced by expectations of success and the perceived value of the task (Eccles & Wigfield, 2002). To succeed in a timely, engaging, effective, and satisfying manner and to accomplish a high-level outcome, students need strong motivation (Halim et al., 2014), either a personal motivation or social motivation to contribute to society. Personal motivation can derive from an early acquaintance with a field, a desire to be exposed to a new field, or a goal to deepen some topic. Social responsibility is becoming increasingly important in today's society, with more and more emphasis being placed on the role of individuals and organizations in creating a better world for all. This trend has also made its way into the academic world, with many universities requiring students to engage in social responsibility initiatives as part of their academic requirements. Choosing a topic for the capstone project can have many constraints, such as project scope requirements, team preferences, and feasibility. Thus some students consider their topic as not a free choice (Braught & Siddiqui, 2022). This study revealed that students from the analysis and design stage of the capstone (second stage) reported having chosen topics out of social motivation and had fewer constraints in comparison to the students in the empirical research seminar (first stage). This can be explained by the maturity of the capstone project's process and the different characteristics of the second stage, being more practical and less theoretical than the first stage. This finding also suggests that students in the analysis and design stage of the project were more likely to choose topics out of social motivation. This may be because students in this stage of the project are able to analyze and make more informed decisions regarding the need and requirements to construct new information systems.

The use of learned knowledge, acquiring new knowledge, and integrating all together to solve the problem they face, are important skills needed in the information systems industry. As previous research claimed (e.g., Sung et al., 2016), high-level prior knowledge is a key factor for successful projects. The integration of different kinds of knowledge allows for better understanding and higher-quality solutions (Mehta & Mehta, 2018; Steiger, 2009). Moreover, technology changes at a very fast pace, so students need to learn, during their undergraduate studies, how to cope with new subjects and investigate them by themselves to solve new problems with new unknown technologies. In this study, students from the analysis and design stage (second stage) of the capstone report about integrating knowledge more than the students in the empirical research seminar (first stage). It suggests that students in the analysis and design stage of the project were more likely to integrate their prior knowledge with new knowledge. This may be because students in this stage of the project have a deeper understanding of the project and need to integrate more subjects from previous courses and new topics to assist them in the completion of the project.

The Skills facets and factors revealed in this research strengthen prior research, which found them as essential employability skills needed by undergraduates to enter the workforce (St. Louis et al., 2021), especially in the field of Information Systems: time management (Auvinen et al., 2020; Cottrell, 2019; Osmani et al., 2019), teamwork (Cimatti, 2016; Matturro et al., 2019), and inter-communication (Idkhan et al., 2021; Kleckner & Butz, 2022). There were no significant statistical differences between the two stages of the capstone project in terms of time management or teamwork. The finding suggests that students were able to maintain similar levels of these skills throughout the project, regardless of the stage they were at. This may be because time management (Lay & Schouwenburg, 1993) and teamwork are fundamental skills that are required throughout the entire capstone project. On the contrary, there were significant statistical differences in inter-communication between the two stages of the capstone project. This finding suggests that students in the analysis and design stage of the project were more likely to use communication with mentors or external entities. This may be because students in this stage of the project are working on a more advanced stage and require more input from external sources.

Overall, the findings of this study highlight the importance of reflection and analysis in the capstone project. By analyzing students' reflections, specific areas for improvement and tailoring the teaching and support to address these areas can be identified. The results also suggest that time management and teamwork are fundamental skills that should be developed throughout the entire capstone project, while inter-communication, knowledge integration, and social motivation require more attention in the later stages of the project. Moreover, it is very important to prepare the students for employability (Jiracheewewong, 2022) by including a "real-life" capstone project at the end of their undergraduate studies in order to prepare the students to be valuable in the workforce, even at their start point as juniors.

CONCLUSIONS

The aim of this study was to investigate the facets and factors that students experienced during a capstone project by analyzing students' reflections at two stages of the project.

As mentioned in the Methodology section, the reflections collected were unstructured, and the students did not receive any instructions on what and how to write their reflections. Thus, students could have referred to any aspects of their work. Nevertheless, they referred to the soft aspects and employability skills. This can be seen as one of the strengths of the current research as it reflects the importance attributed by the students to the capstone project's contribution.

The results showed that the three main facets identified in the students' reflections were motivation, knowledge, and skills, as presented in Figure 2. The skills facet revealed three main factors: Teamwork, Time management, and Inter-communication, which are important employability skills needed in today's fast-changing and demanding industry. The qualitative analysis identified recurring themes in each facet, and a conceptual framework was developed to illustrate the factors of each facet. The quantitative analysis revealed that there were no significant differences between the two stages of the capstone project in terms of time management and teamwork, but there were significant differences in inter-communication, knowledge integration, social motivation, and motivation constraints.

The findings of this study provide useful insights into the facets and factors that are important to students during a capstone project in Information Systems studies. It is highly recommended for IS faculty, teachers, and mentors emphasize the importance of developing employability skills during the capstone project to prepare undergraduate students for the workforce. This can be done through specific well-designed guided instruction and workshops in addition to ongoing personal and team reflections throughout the capstone project.

LIMITATIONS

Several limitations must be considered when interpreting the results of this study. The data collection was limited to the students in one higher education institution. Moreover, and in addition to the advantages specified in the conclusions, the reflections collected were unstructured and can also be seen as a limitation. The students did not receive any instructions on what and how to write their reflections. Thus, the lack of references on some of the facets and factors in some of the reflections cannot indicate the students did not experience them.

FUTURE WORK

To evaluate the process of employability skills development, a further study can examine students' perceptions prior to the capstone, during, and after to assess the progress and changes. Students' readiness for the industry and their employability skills are extremely important in all disciplines. It would be valuable to investigate whether the findings of this study are consistent across different institutions and disciplines. This would help to establish the generalizability of the results. The study could be extended to explore the impact of the identified facets and factors on project outcomes, such as the quality of the final product or student satisfaction. In addition, it is recommended to conduct a confirmatory analysis to measure the relationship and influence of each of the model's components.

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DATA SCIENCE EDUCATION – A SCOPING REVIEW

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ABSTRACT

Aim/Purpose	This study aimed to evaluate the extant research on data science education (DSE) to identify the existing gaps, opportunities, and challenges, and make recommendations for current and future DSE.
Background	There has been an increase in the number of data science programs especially because of the increased appreciation of data as a multidisciplinary strategic resource. This has resulted in a greater need for skills in data science to extract meaningful insights from data. However, the data science programs are not enough to meet the demand for data science skills. While there is growth in data science programs, they appear more as a rebranding of existing engineering, computer science, mathematics, and statistics programs.
Methodology	A scoping review was adopted for the period 2010–2021 using six scholarly multidisciplinary databases: Google Scholar, IEEE Xplore, ACM Digital Library, ScienceDirect, Scopus, and the AIS Basket of eight journals. The study was narrowed down to 91 research articles and adopted a classification coding framework and correlation analysis for analysis.
Contribution	We theoretically contribute to the growing body of knowledge about the need to scale up data science through multidisciplinary pedagogies and disciplines as the demand grows. This paves the way for future research to understand which programs can provide current and future data scientists the skills and competencies relevant to societal needs.
Findings	The key results revealed the limited emphasis on DSE, especially in non-STEM (Science, Technology, Engineering, and Mathematics) disciplines. In addition, the results identified the need to find a suitable pedagogy or a set of pedagogies

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	because of the multidisciplinary nature of DSE. Further, there is currently no existing framework to guide the design and development of DSE at various education levels, leading to sometimes inadequate programs. The study also noted the importance of various stakeholders who can contribute towards DSE and thus create opportunities in the DSE ecosystem. Most of the research studies reviewed were case studies that presented more STEM programs as compared to non-STEM.
Recommendations for Practitioners	We recommend CRoss Industry Standard Process for Data Mining (CRISP-DM) as a framework to adopt collaborative pedagogies to teach data science. This research implies that it is important for academia, policymakers, and data science content developers to work closely with organizations to understand their needs.
Recommendations for Researchers	We recommend future research into programs that can provide current and future data scientists the skills and competencies relevant to societal needs and how interdisciplinarity within these programs can be integrated.
Impact on Society	Data science expertise is essential for tackling societal issues and generating beneficial effects. The main problem is that data is diverse and always changing, necessitating ongoing (up)skilling. Academic institutions must therefore stay current with new advances, changing data, and organizational requirements. Industry experts might share views based on their practical knowledge. The DSE ecosystem can be shaped by collaborating with numerous stakeholders and being aware of each stakeholder's function in order to advance data science internationally.
Future Research	The study found that there are a number of research opportunities that can be explored to improve the implementation of DSE, for instance, how can CRISP-DM be integrated into collaborative pedagogies to provide a fully comprehensive data science curriculum?
Keywords	data science applications in education, pedagogy, teaching/learning strategies, transdisciplinary projects, data science education

INTRODUCTION

Data science offers actionable insights by mining structured and unstructured data using statistical and computational tools and methods to identify patterns. It is a growing field impacting various sectors, genres, and disciplines, and therefore places the spotlight on data science education (DSE) (Van Dusen et al., 2019). DSE is an umbrella term used to describe learning programs meant to equip data scientists with data science competencies and skills mainly from computer science, mathematics, statistics, engineering, psychology, and the domain of interest. This multidisciplinary nature of data science programs means that DSE is an integration of knowledge, methodologies, or techniques from different distinct disciplines into a unique and distinct discipline of its own. Nonetheless, data science is framed more as a Science, Technology, Engineering, and Mathematics (STEM) discipline (McMaster et al., 2011; Rosenthal & Chung, 2020; Twinomurinzi et al., 2022) with little emphasis on business domains.

The demand for data scientists with the appropriate skills is high (World Economic Forum, 2019) and is evident in the increasing number of data scientist job vacancies (Verma et al., 2019), and the mushrooming of many formal learning programs (at undergraduate and postgraduate levels) and short learning programs (Saltz, Armour, & Sharda, 2018). However, there is limited alignment between these learning programs; there is therefore a gap between academic data science and commercial data science (Berman et al., 2018). There are also inconsistencies among the existing learning programs. Organizing learning programs around data science process models has been suggested (Haynes et al., 2019; Jaggia et al., 2020).

The most consistent model for data science remains the CRISP-DM model (Saltz, 2021). CRISP-DM has been heavily adopted for data science projects and has been deemed useful in teaching data analytics (Jaggia et al., 2020; Kristoffersen et al., 2019). The major features of this model are its independence of technology and industry sectors (Ayele, 2020).

It is important to appreciate that data scientists support various sectors with a variety of data from different sources (Heinemann et al., 2018). Consequently, this raises the need to understand and create DSE curricula (Kross et al., 2020) that target all transdisciplinary competencies including practical skills that are linked to different domains (Dill-McFarland et al., 2021; Mokiy, 2019). The nature of data science demands different teaching and learning structures that are not constrained (Irizarry, 2020) but promote a collaborative environment to avoid teaching data science in silos (Mikroyannidis, Domingue, Bachler, & Quick, 2018). Nevertheless, the multiple disciplines that jointly form data science bring multiple opportunities and challenges to DSE (Danyluk et al., 2019).

There is therefore a growing call for standardising DSE (Heinemann et al., 2018; Irizarry, 2020), especially in the field of curriculum design (Chen, 2020; Finzer, 2013; Mikroyannidis et al., 2018; Song & Zhu, 2016). For instance, several academic workshops (panel sessions) and conferences have been hosted with the intent to discuss data science curriculum design (i.e., Danyluk et al., 2019; Howe et al., 2017; Mikroyannidis, Domingue, Phethean, et al., 2018; Oh et al., 2019; Van Dusen et al., 2019). However, these are still developing opportunities that might introduce some beneficial recommendations to improve DSE. Therefore, the following research question was formulated to understand the status of DSE:

> *How has DSE been investigated, and what are the gaps, opportunities for, and challenges associated with DSE?*

We theoretically contribute to the growing body of knowledge about the need to democratize data science, making it accessible to a broader range of individuals through multidisciplinary pedagogies and disciplines as the demand grows. Democratizing data science refers to the efforts aimed at making data science accessible and inclusive to a wider audience. Traditionally, data science has been associated with technical expertise and specialized skills, which have limited its accessibility. However, democratization seeks to break down these barriers and empower more people to participate in and benefit from the field of data science. This paves the way for future research to understand which programs can provide current and future data scientists the skills and competencies relevant to societal needs.

This study adopted a scoping review methodology to assess the status of DSE research since 2010 with specific attention paid to articles describing DSE, opportunities available in DSE, and challenges faced by DSE. The remainder of the paper is structured as follows: after presenting the methodology adopted and discussing the findings, this scoping review concludes with conclusions, implications, limitations, and areas for further research.

RESEARCH METHODOLOGY

Scoping reviews are conducted with the intent to identify pertinent published studies that address a specific research question. The primary purpose is to synthesize a body of knowledge related to the phenomena of interest (Siddaway et al., 2019). The sections that follow elaborate further on the broad criteria considered when conducting this scoping review.

Protocol

The study adopted the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to maintain transparency in reporting the findings of this study (Knobloch et al., 2011; Shamseer et al., 2015). To improve study quality and minimize biases, the inclusion and exclusion criteria were established *a priori* as suggested by Nightingale (2009).

Eligibility Criteria

The eligibility criteria were set as studies and academic reports published during the 12 years from 2010 to 2021. Papers reporting on working groups and panel sessions, and out of scope, were not included. Only papers published in the English language were eligible for inclusion.

Search Words and Data Sources

The keywords and data sources used to search for relevant and authoritative research papers for the systematic literature review are listed in Table 1.

Table 1. Search keywords and data sources

Search keywords	Data sources
DSE	Google Scholar
Big DSE	IEEE Xplore
Data Science Curriculum	ACM Digital Library
Data Science Curricular	ScienceDirect
Data Science Program	Scopus
Data Analytics Education	**AIS basket of eight journals**
Data Science Training	*Information Systems Journal*
Data Mining Education	*Journal of the Association for Information Systems*
Knowledge Discovery	*Journal of Information Technology*
Data Science Learning	*Journal of Management Information Systems*
	Journal of Strategic Information Systems
	Management Information Systems Quarterly
	European Journal of Information Systems
	Information Systems Research

Searching Process

The following search string was used across the data sources to retrieve the papers from the various sources listed in Table 1.

> ("Data science*" OR "Big Data*" OR "Data mining*" OR "Data analytics*" OR "Knowledge discovery*") AND ("Education*" OR "Curriculum*" OR "Training*" OR "Program*" OR "Learning*")

Selection of Studies

The selection criteria of the relevant papers are dependent upon the research question. The systematic literature review employed the pre-defined selection criteria for the selection of papers to be included in the review (Table 2).

Table 2. Inclusion, exclusion, and quality assessment criteria

Inclusion criteria	Exclusion criteria	Quality assessment of studies
The research paper is peer-reviewed. The research is related to the search string and area of "DSE". Research published between 2010 and 2021. The selected study must be a full-length published paper. Research publications must be written in the English language.	Papers published before 2010. Unpublished studies. Papers are not written in English. Papers not related directly to the research question (i.e., opportunities and barriers reported on DSE/curriculum).	As part of the quality assessment, each study was checked against the following questions: Is the study in relation to DSE? Does the paper provide a clear statement of findings? Is the paper peer-reviewed? Is the paper published in a reputable source?

Figure 1 depicts the process followed to select the final list of peer-reviewed research articles for inclusion in the systematic literature review. The preliminary search denotes the number of papers retrieved (research hits) after running the search string. The first order of selection was based on the review of paper keywords, title, and abstract. In the second order of selection, all duplicated research papers were eliminated. In the third order of selection, all papers that did not meet the eligibility criteria were discarded. The articles were accepted based on the selection criteria outlined in Table 3.

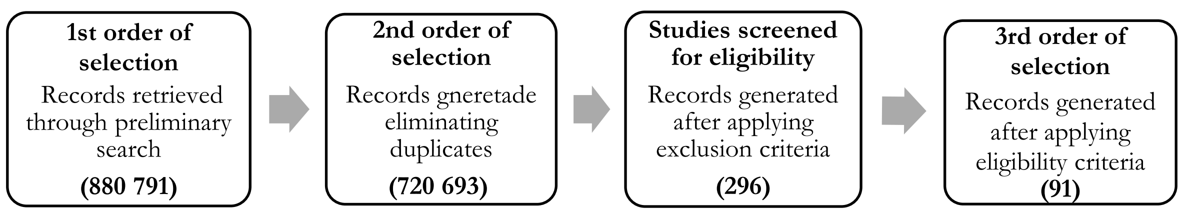

Figure 1. Order of selection of the papers for the systematic literature review

Table 3. Selection criteria

Acceptable in 1st order of selection	Acceptable in 2nd order of selection	Acceptable in 3rd order of selection
Abstract and keywords are accessible. Acceptable study types are journal or conference papers (peer-reviewed). Language is English Study publication date is within the 2010-2021 period.	Abstract and keywords are accessible. Acceptable study types are journal or conference papers (peer-reviewed). Paper is written in the English language. Study publication date is within the 2010-2021 period. Studies are unique (not duplicates).	Full text of the article is accessible. Acceptable study types are journal or conference papers (peer-reviewed). Paper is written in the English language. Study publication date is within the 2010-2021 period. The study focuses on DSE or is within the scope. Studies are unique (not duplicates).

Data Collection Process

The systematic literature review of the selected research papers was conducted based on the inclusion and exclusion criteria. The data collection process was conducted during the period from July 2021 to September 2021. The data collection process was monitored and reviewed by the co-authors of this study. Data extraction included demographic details, origin (continent), methodology, focus, and other aspects.

Framework for Analyzing the Eligible Papers

After collecting the eligible research papers, the study applied the classification and coding framework of Amui et al. (2017) to provide structure to the existing body of knowledge around the phenomena of interest. As shown in Appendix A, this framework uses numerical and letter codes to categorize the chosen papers.

Findings

A descriptive and correlation analysis was performed to understand the relationships between the different classes tabled in Appendices A and B. A statistical correlation analysis was included because the number of papers reviewed was enough to draw statistical and inferential insights into the strengths and directions of relationships between the different aspects of DSE. Due to space constraints, only highly significant inferences are discussed.

Distribution of DSE Publication by Continent

The initial analysis focused on the distribution of the articles according to the regional geographical location or area in which the selected DSE articles were published. Figure 2 shows the distribution of the selected DSE articles based on the continent in which the studies were conducted.

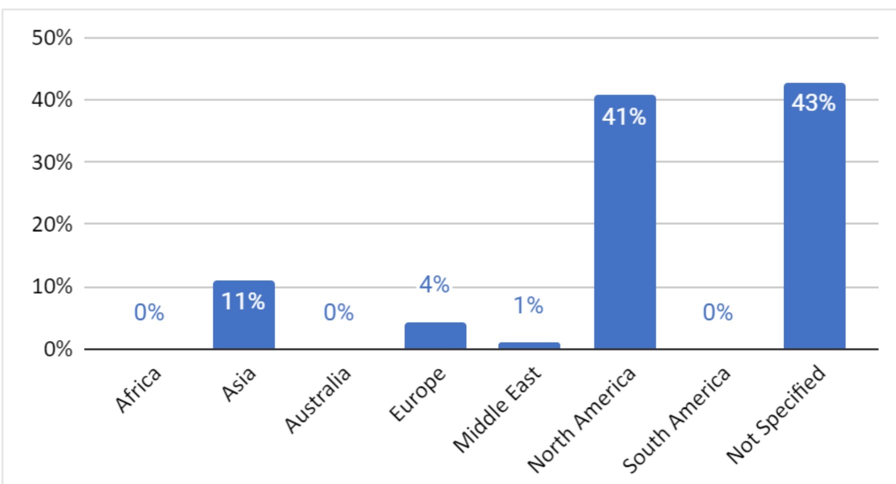

Figure 2. Paper distribution by continent

As can be seen from Figure 2, North America is the main contributor to DSE research, with 27 publications being published; this accounts for 41% of the papers published during the period 2010 to 2021. A similar trend has been observed in other studies (Farahi & Stroud, 2018; Hassan & Liu, 2020). A slightly higher number of studies (43%) did not specifically indicate the country of origin of their publications. The low number of DSE articles published in Asia (11%), Europe (4%), and the Middle East (1%) suggests that limited DSE research is being carried out in these continents. The low number of DSE papers emanating from Europe (4%) and Asia (11%) are surprising

(Mikroyannidis et al., 2018). No studies were recorded for Africa, Australia, and South America during the same period.

A correlation analysis (Appendix B) revealed that most of the research conducted in North America focused on project-based learning as a teaching strategy for DSE. North America is where most global technology companies such as Microsoft and Google (Luna et al., 2014) are located. Developing countries are not well-positioned to realize the need to derive benefits from data science (Hack-Polay et al., 2020; Shereni & Chambwe, 2020). Such countries often face various challenges such as poor infrastructure and the absence of skills thus putting the continents in which these countries are located at a disadvantage (Luna et al., 2014; Shereni & Chambwe, 2020; Takemura, 2018). It is also possible that the demand for data science has not advanced as much in these countries hence the limited research.

Classification According to (Based on) the Research Method

The use of appropriate research methods is important in any study to answer the research questions. Figure 3 shows that the research methods adopted in the selected papers ranged from experimental methods, surveys, action research, ethnography, and case studies to design science (design and creation) (Oates, 2006).

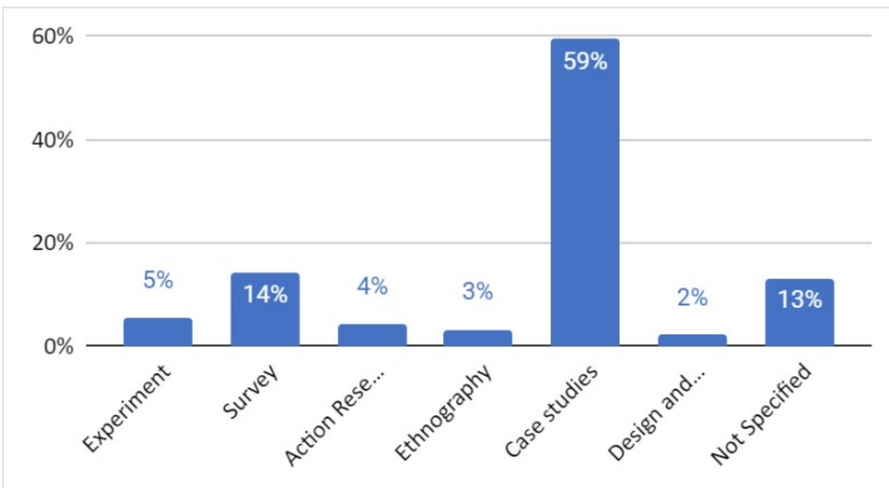

Figure 3. Article distribution based on the research methodology

The case study method was the most used research method (58%) followed by the survey method (14%), the experiment research method (5%), action research (4%), ethnography (3%), and design science (2%). According to Rowley (2002), case studies provide an appropriate platform to investigate emerging areas or projects that are in the exploratory phase. The preference for case studies as a research method suggests that DSE is indeed an emerging topic of interest.

It is evident from the findings of this scoping review that considerable attention was being paid to addressing the challenge of data science skills gap as several case studies reported on how modules can be adopted for use by data scientists (Buzydlowski, 2019; Çetinkaya-Rundel & Ellison, 2021; Facey-Shaw et al., 2018); other case studies focused on rebranding STEM courses (Bart et al., 2016; Buzydlowski, 2019; Kahn, 2020; Rao et al., 2018; Yadav & Debello, 2019). Only a single case study was reported that focused on non-STEM (Gil, 2014); another one was targeted at non-programmers (Jie et al., 2020). Furthermore, it is noteworthy that few trades involve DSE, such as the medical field (Garmire et al., 2017; Otero et al., 2014) and the engineering field (Qiang et al., 2019). The papers also recommended teaching practices and technologies suitable for DSE.

It is notable that none of the selected papers incorporated more than one research method. While case studies may be an appropriate method to investigate emerging areas or projects that are at the exploratory stage (Rowley, 2002), using a single method to investigate a particular problem may not be sufficiently rigorous (Chung et al., 2020). More specifically, multiple methods would offer different aspects of DSE; for example, the adequacy and effectiveness of DSE learning programs.

Analysis by Qualification Level at Which DSE is Offered

The two models available to the public for delivering content can be roughly classified as formal and non-formal. Formal DSE is offered from school to tertiary level, while informal DSE is often autodidactic. The distinction between formal and autodidactic depends on where they are offered and the content of the programs. Other DSE programs such as micro-credentials and short-learning programs can be offered formally or autodidactically at various levels. Figure 4 shows the various qualifications levels at which DSE is offered.

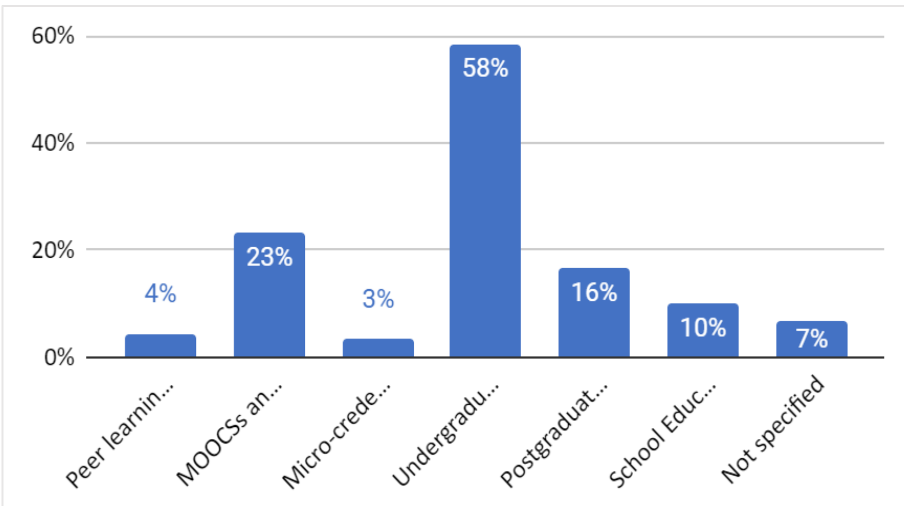

Figure 4. Article distribution per level of qualification

Figure 4 shows that the undergraduate program is the most researched DSE qualification making 58%. MOOCs and short learning programs were mentioned in less than half of the papers (23%), only, 16% and 10% of the reviewed papers mentioned postgraduate programs and school education as the most appropriate level for imparting DSE. The number of papers mentioning peer learning and micro-credentials for delivering DSE was significantly low at 4% and 3% respectively. Of the reviewed papers, 7% did not specify the level of qualification mooted for DSE. There is therefore an opportunity to consider different educational levels to introduce and offer DSE.

Analysis by DSE Discipline

Data science integrates different disciplines yet Figure 5 suggests that some disciplines appear to be more dominant than others, which makes it difficult to maintain the transdisciplinary trait of the learning program.

It is evident that the STEM (Science-Technology-Engineering-Mathematics) type disciplines account for the highest number of DSE research, mainly computer science (40%), followed by statistics (37%). About 33% of the publications did not specify the discipline of interest and instead just gave a broad description of "data science." For instance, Saltz, Dewar, and Heckman (2018) focus on teaching ethics in DSE while Wymbs (2016) looked at how data analytics can be incorporated into undergraduate business programs.

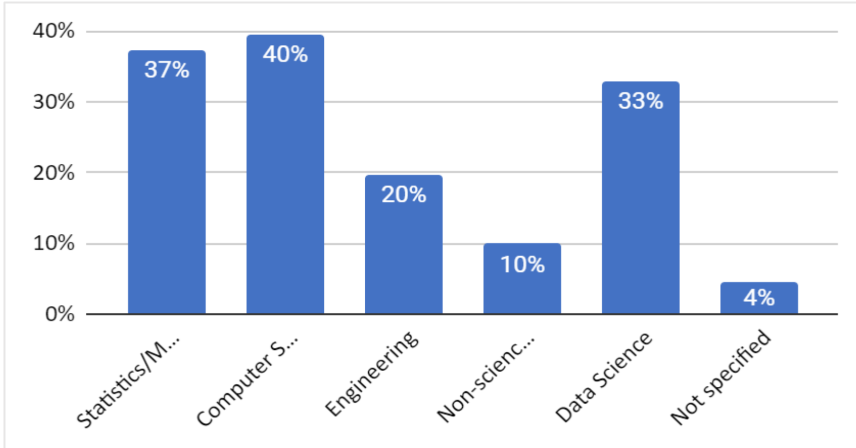

Figure 5. Article distribution per data science discipline

It was not clear how much of each element should be featured in DSE to balance the multidisciplinarity. However, the non-STEM domains appeared to be receiving less attention compared to other data science elements. This is possibly because DSE programs are often offered within the faculties of sciences and engineering (Gil, 2014), and little attention is given to the applicability to other disciplines.

The study showed a positive correlation between the engineering component of data science and the use of technology, presenting an opportunity for researchers and practitioners to propose strategies on how technology can be used to teach data science. This is informed by a lack of integrated platforms where students can develop hands-on experience (Zhang et al., 2017).

The study further showed that the CRISP-DM phase (Evaluation) and discipline-specific (non-STEM) domain are significantly correlated. This implies that rather than teaching students how to develop models, non-STEM education focuses on evaluating models to determine whether the suggested model is in line with the business objectives and actually solves the business problem.

Analysis of DSE Providers

DSE is offered by various educational service providers including public institutions, private institutions, industry organizations, and through collaborative partnerships (Figure 6).

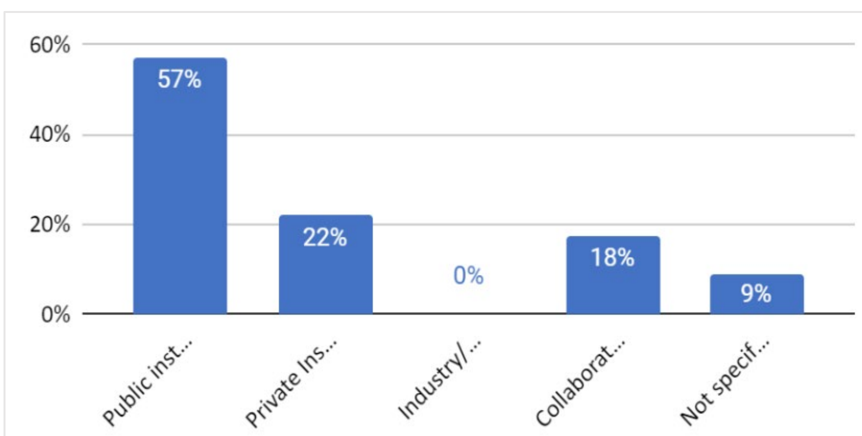

Figure 6. Article distribution per data science educational provider

As shown in Figure 6, most of the papers (57%) report data science programs being offered by public institutions of learning. Whereas 22% of the papers claim that DSE is offered by private institutions of learning, only 18% have reported DSE collaborative initiatives involving both the public and private sectors.

First, public institutions benefit from the teaching and learning funding model to support DSE through sourcing qualified lecturers and conducting research related to data science and DSE. For instance, Demchenko et al. (2017) presented a data science course that was funded by the European Commission, and Heinemann et al. (2018) presented a data science education for secondary schools that was funded by Deutsche Telekom Stiftung.

Second, public institutions typically have extensive interfaculty support systems in place, as well as external support from other institutions (Huppenkothen et al., 2018). Collaboration with international institutions is an important aspect of the external support system because it enables to access information and resources that are normally not easily accessible, and thus be part of ongoing studies that cover new trends in data science (X. Li et al., 2019).

Third, there is a high preference for public university qualifications among students over those offered by private institutions. Public universities are in a better position to implement DSE, however, there are challenges concerning peer learning results showing a negative correlation. A contributing factor may be the absence of policies that encourage and acknowledge peer learning as well as well-researched and widely accepted methods of student assessment.

The results further showed that public institutions of higher learning have less interest in MOOCs and short-learning programs. Private institutions have recently shifted their focus towards offering more data science short learning programs, MOOCs, and badges due to the high demand for data science programs. However, there is a need to focus more on the quality and relevance of the learning content rather than the number of programs offered. Collaboration may increase opportunities for developing collaborative DSE that captures the interests of various stakeholders.

Analysis of the Data Science Context Using the CRISP-DM Model

This study examined CRISP-DM as the most consistent transdisciplinary framework to guide data science projects and teaching. The purpose was to determine the extent to which DS programs are aligned with the model (Jaggia et al., 2020). Figure 7 shows the paper distribution across phases of the CRISP-DM model.

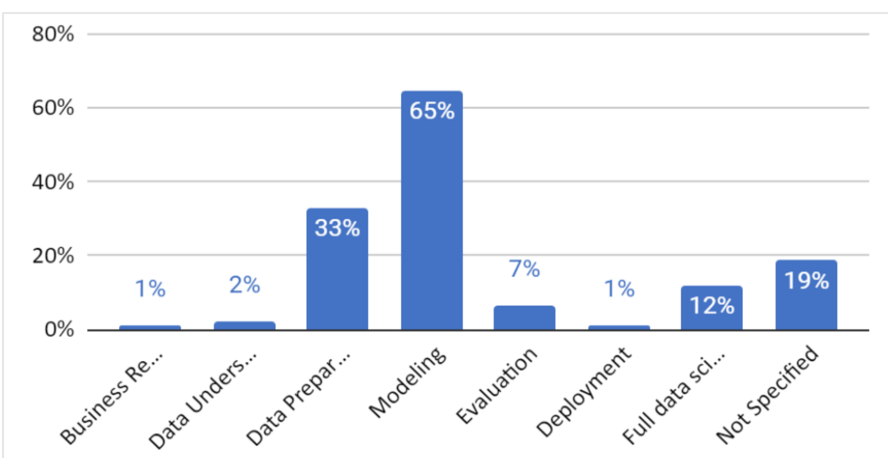

Figure 7. Article distribution per data science context based on CRISP-DM

According to Figure 7, an overwhelming majority of the papers (65%) emphasize the inclusion of data modeling in DSE, while slightly over half of the selected papers (33%) are inclined toward data preparation. Furthermore, only 12% of the selected papers appear to punt the inclusion of all phases of CRISP-DM in DSE. Evaluation was mentioned in 7% of the papers, while data understanding was mentioned in 2% of the papers. The idea of including evaluation (7%), data understanding (2%), and business understanding and deployment (1%) components in DSE does not appear to be favored by many researchers. A substantial number of papers (19%) did not express any preference for the inclusion of any specific CRISP-DM phase in DSE.

These results suggest that current DSE research does not give priority to all the CRISP-DM phases, and this affects the inclusion of these phases in the data science curriculum and limits the development of data science skills amongst students. These findings support Gil's (2014) argument that DSE focuses more on databases and machine learning contexts neglecting other elements.

Data science is applied across various industries; therefore, data scientists need to master the technical skills of data science (i.e., data mining and analysis, machine learning, and others) as well as business skills (i.e., marketing, data products, and others) (Qiang et al., 2019). Data science specialists should be able to participate in the whole data science lifecycle, mimicking the CRISP-DM model (Donoghue et al., 2021). Without these skills, organizations are deprived of the opportunity to use data to create a competitive advantage and to make smart decisions.

The results also demonstrated that business requirements as part of DSE can be offered through collaborations (Paul & Aithal, 2018). This finding suggests the existence of an opportunity for different stakeholders to work together and develop data science modules that focus on business understanding as the first phase in data science projects. This will allow data scientists to develop competencies to participate in the business requirement-gathering process and understand the business or economic side of data science before they can proceed with data wrangling. Organizations' focal points vary; therefore, collaboration with and amongst these organizations creates a setting where objectives and interests are shared while engaging a transdisciplinary DSE.

Analysis of Teaching Strategies

Data science is transdisciplinary and is therefore expected to adopt various teaching methods and tools. Figure 8, however, shows that there are mainly four teaching strategies adopted for DSE, namely competency-based learning (54%), use of technology (53%), teacher-led (49%), and project-based learning (44%). Flipped classroom (14%), student-led learning (9%), personalized learning (7%), and inquiry-based learning (4%) are not as popular. Only 13% of the papers did not mention any teaching strategy.

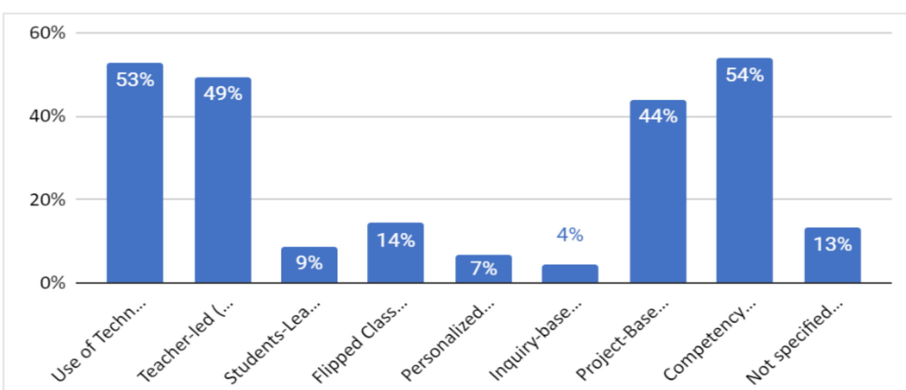

Figure 8. Distribution of publications by teaching strategies

There is a need to investigate more instructional approaches that will enable students to easily understand difficult concepts within DSE. For instance, the correlational analysis showed that flipped classrooms (especially pre-recorded videos) are mostly applied in micro-credential courses. Flipped or flexible classrooms and micro-credentials rank amongst the top new developments changing the education system (Klašnja-Milićević et al., 2017).

Strategies for improving DSE

The literature suggests that DSE opportunities have unfortunately not fully emerged (Finzer, 2013). Figure 9 shows the distribution of papers as per outlined opportunities based on the existing literature.

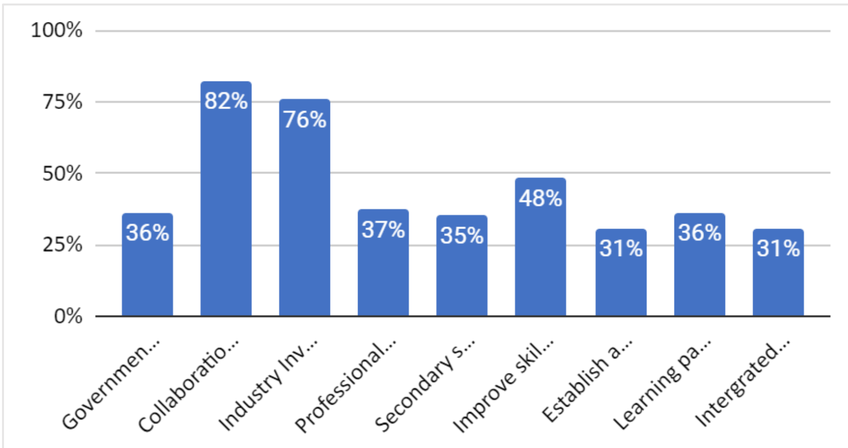

Figure 9. Article distribution as per outlined opportunities

Collaboration Between Universities (82% of the Papers)

Based on the data presented, the collaboration amongst university faculties presents an opportunity for the implementation of DSE. Some of the opportunities presented by collaboration amongst universities include sharing resources, such as lecturers, in cases where there is a lack of skills and capacity. Attwood et al. (2019) noted that it is often difficult to find suitably qualified candidates for DSE lecturing posts. Mostly, the technical aspects of data science can be crucial and can be immensely beneficial when more resources are available (Cleveland, 2001). Therefore, collaboration among universities can accelerate the creation of an environment where data science exists as a cross-campus endeavor that involves faculties and students in different departments (Van Dusen et al., 2019).

An opportunity also exists for universities to make available educational data that can be shared across different disciplines. However, such a collaborative approach will require regulating standards (both local and international) to address issues of ethics, security, and privacy (Daniel, 2019).

Involvement of Industry (76% of the Papers)

Organizations that have both data and data science skills have a competitive edge (Takemura, 2018), and understand the needs problems (Cybulski & Scheepers, 2021). Involvement and collaboration with organizations can provide academic institutions with some perspectives in terms of linking the teaching and learning content with real business scenarios. Furthermore, this provides opportunities for students and lecturers to access data for simulation purposes. With that, students get to be well prepared for the real working environment and organizations can recruit from a pool of well-qualified data scientists. Most importantly, DSE programs can be designed and developed with input from both nationally and internationally renowned industry experts and leading practitioners (Demchenko et al., 2015).

Improve Skills at the Tertiary Level (48% of the Papers)

Whereas a high increase in data science programs is being experienced, the challenge of skills complement among lecturing staff at universities remains. It is difficult to teach specialized data science skills when lecturing staff members do not, at the very least, have experience in the field. This limitation hinders DSE offering, especially at various levels of tertiary education. Academics teaching at this level may not be able to demonstrate all the techniques that data science students need to acquire (Paul & Aithal, 2018; Song & Zhu, 2016). Essentially, improving the skills of academic staff members will allow full data science participation from the secondary school level, and at the tertiary level. Not only would the availability of these resources support teaching, but also the development and continued review of DSE.

Professional Advancement (37% of the Papers)

Data science as an emerging field does not have many qualified professionals available with the requisite experience (Mikalef et al., 2018). There is therefore a need for re-skilling and upskilling the capabilities of those involved in DSE. The rapid change in technology means the modeling techniques are also rapidly evolving. This means that data scientists must adapt relevant skillsets continuously to suit business requirements. Staying relevant in a changing world is rewarding but it can also be time-consuming (Çetinkaya-Rundel & Ellison, 2021). To remain relevant, DSE needs to be flexible and agile enough to accommodate future developments in data science tools, models, and technologies for data science.

Government Involvement (36% of the Papers)

Government entities can take part in the implementation of DSE in a variety of ways, such as making available data for educational purposes. Open data is valuable when educating students about data concepts and, where possible, providing them with real business stories (Saddiqa et al., 2021). Integrating real data sets within data science courses could enable the development of data science skills, such as data collection, cleaning, analysis, and interpretation. Government can also benefit from these initiatives. Initiatives towards open government data can guide innovation and improve service delivery and involve citizens in decision-making processes.

Learning Pathways (36% of the Papers)

With unpredicted changes in the future of work and evolving technology, it is important to consider how students progress from the time they enroll, how they progress with their studies, and how their careers become real and change beyond studies (Iatrellis et al., 2020; Lyon et al., 2015; Miller & Hughes, 2017). The multidisciplinarity of data science offers options as a path for specialization, such as data engineering, machine learning, and algorithm development. In addition, data science serves multiple fields and there are key players and different career pathways in each field (Misnevs & Yatskiv, 2016).

Secondary School Curriculum (35% of the Papers)

Introducing data science into a secondary school curriculum was identified as an opportunity in 35% of the selected publications. This may assist students in acquiring some substantive data science competencies at a foundation level. However, the challenge lies in integrating data science into secondary school subjects so that students develop data science skills and the conceptual understanding needed to participate fully in society as citizens and workers (Finzer, 2013).

There is also the challenge of teachers with computational and mathematical skills to transfer knowledge to young aspiring data scientists. The majority of teachers are not trained nor have experience in DSE (X. Li et al., 2019). For instance, teachers are having challenges with programming languages such as R and this affects their statistical analysis capabilities (Gould et al., 2016). The improvement of DSE at the school level by ensuring that teachers are trained in data analytics and have experience working with data can potentially advance data proficiency and awareness (Biehler et al., 2018).

Establishing a DSE Governing Body (36% of the Papers)

This consortium can serve as the advisory board for content creation and review where necessary. So far, there are no guiding frameworks for DSE, hence the inconsistencies in the learning programs. Within organizations, some problems can be addressed fully or can be moderately solved, or automated through data science (Cybulski & Scheepers, 2021). These developments should be communicated with DSE institutes so that learning programs can focus more on the areas that cannot be automated. This calls for a guided process which can be achieved by having a governing body or a framework for implementation. Research on how this can be implemented is now significant. This can be local or global or, even better, it can be through a collaboration.

Integrated Digital Platforms (36% of the Papers)

Institutions need to investigate the implementation of integrated digital platforms for effective data science programs. Platforms add value by allowing students to have a simulated project, share resources, and execute data analysis. Cloud-based technologies are also a valuable tool for teaching data science, as they are quick to set up and allow an intuitive environment.

Analysis of Challenges in DSE

This category is aimed at identifying the challenges in DSE. Designing a transdisciplinary curriculum and training data scientists pose several challenges (Mikroyannidis et al., 2018). There were 11 themes on the challenges in DSE (Figure 10).

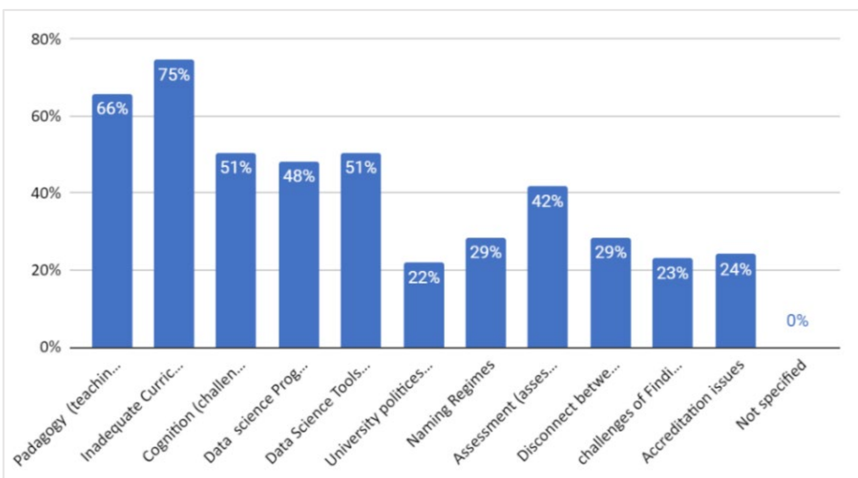

Figure 10. Article distribution based on DSE challenges

Inadequate Curriculum in DSE

The inadequate curriculum appears to be a major challenge in DSE and was noted by 75% of the publications. It is therefore quite clear that the issue of addressing inadequate curriculum in DSE is very critical. For instance, not developing data scientists with the competencies and skills to understand the domain as well as the business context presents an extra cost for organizations. Although data science is focused on statistical and computational thinking, it is also applied to solving domain-specific problems (Blei & Smyth, 2017). Therefore, it may prove difficult for data scientists to link data science outputs with organizational objectives. Inadequate curricula lead to inadequate competencies. While extant literature has also demonstrated a lack of consistency in DSE, specific recommendations to address these issues are scant.

Teaching Pedagogies

Challenges related to teaching pedagogies were highlighted by 66% of the selected papers It is noted that teaching modern data scientists is a challenge (Mikroyannidis et al., 2018; Oudshoorn et al., 2020). In sentiments shared by scholars, data skills cannot be taught using only direct instruction (Hardin et al., 2015; Mike, 2020; Takemura, 2018). Project-based pedagogies have been mentioned as one of the appropriate pedagogy for teaching data scientists (Donoghue et al., 2021; Saltz & Heckman, 2016; Takemura, 2018). Other teaching practices have been applied to promote data skills, such as gamification (Hee et al., 2016), and social student events like hackathons and datathons (Anslow et al., 2016; Huppenkothen et al., 2018). The common features among the mentioned teaching practices are that they are student-centered, and enforced hands-on learning that integrates real business scenarios and data (A. Y. Kim et al., 2018), and the ability to scale up data science (Donoghue et al., 2021). Topics on teaching pedagogies are not often initiated, yet so many individuals who graduate proceed to take teaching roles (Cleveland, 2001).

Cognitive Skills (Understanding of Challenging Concepts)

A lack of cognitive skills was mentioned as a challenge in 51% of the papers reviewed. In general, the reviewed papers pointed out statistics, mathematics, and programming as being challenging subjects where students have to apply their minds when solving problems that apply to these concepts.

Data Science Tools (Model Misuse, Misinterpretation of Models)

A significant number of the papers (51%) mentioned challenges associated with data science tools in DSE. As organizations adopt data science for various business practices, the models must be used appropriately to make practical predictions and well-informed business decisions (Blei & Smyth, 2017). Competencies and skills to work with data platforms, models, and tools to develop and operate data analytics applications effectively are of great significance and should be part of DSE (Wiktorski et al., 2019).

Data Science Program Structure

The structural issues of data science programs were mentioned in 48% of the papers. The findings of this study complement prior studies on DSE that have continuously mentioned the design of DSE as a problem (Clayton & Clopton, 2018; Cybulski & Scheepers, 2021; Twinomurinzi et al., 2022). Currently, only computer sciences and engineering dominate the current structure of DSE (Paul & Aithal, 2018). The dominance may indicate that universities are simply producing data scientists who are computer scientists with no real transdisciplinary expertise (Xia & Li, 2020). It needs to be understood that each industry has different needs, and they explore data science in different ways.

Assessment Issues

While there are various strategies for acquiring data science skills, assessing and validating competency remains a challenge. This challenge was mentioned in 42% of the papers. For instance, students can take part in hackathons or datathons where intensive learning opportunities and skills development exists (Dill-McFarland et al., 2021; Huppenkothen et al., 2018; Msweli, 2023). Although these events expose students to real-world data, it is often difficult to assess and validate the competency of the candidate in various areas of data science.

Naming Regimes

An estimated 29% of the papers registered the challenge that comes with diverse names of data science programs. The inconsistencies in data science program structures affect the identification of these programs (Saltz, Armour, & Sharda, 2018). For instance, Havill (2019) used "Data Analytics" instead of "Data Science" in learning programs to attract a diverse pool of students. Pettis et al. (2018) referred to the same as big data analytics programs, and Jafar et al. (2016) used "data analytics" to refer to both data and business analytics. All these programs differ in terms of programming competence and the degree of statistical abilities expected from students (Saltz, Armour, & Sharda, 2018).

The Disconnect Between Industry Practice and Data Science Learning Material

Based on the analysis of the reviewed papers, there is no shared framework for DSE. This makes the growth of data science learning programs unfocused due to the absence of agreed learning outcomes (Raj et al., 2019). This important element was mentioned in 29% of the papers. The implications of such a disconnection result in data education being driven from one side (often by the industry) (Farahi & Stroud, 2018). Having specific learning outcomes and competencies could help stakeholders such as lecturers, employers, and policy-makers, to have a mutual understanding of the specific skills, competencies, and knowledge that data science students should acquire (J. Kim, 2015).

Accreditation

The accreditation of data science learning programs is lacking and challenging (D. Li et al., 2021). Based on the reviewed papers, the accreditation issues were mentioned in 24% of the papers. As an emerging discipline, there is a mutual understanding that the DSE guidelines and the accreditation criteria are still under development; therefore, it can be assumed that the existing data science programs are built on emerging standards (Oudshoorn et al., 2020).

Finding Organizations Willing to Participate

While the involvement of industry in DSE can bring some structure and insights on relevant content, it is difficult to find industries that are willing to participate in curriculum development (Bohler et al., 2017); this was mentioned in 23% of the papers. To become involved in DSE, organizations will need to avail resources such as practitioners, specialists, or infrastructure. It is not easy to convince organizations to buy into developing initiatives where benefits are not guaranteed (Iatrellis et al., 2020). With the diversity of data science functions across different industries, the nature of skills and competencies required in each function also varies (Radovilsky et al., 2018) . Therefore, organizations need to participate in DSE to ensure the connection between education and competencies needed in the working environment.

University Politics

The transdisciplinary nature of data science exacerbates collaboration challenges. These challenges do not only exist in the workplace but also within tertiary institutions (Anderson et al., 2015; Finzer, 2013). Not only are the faculties affected by these university politics, but lecturers and students as individuals as well. Twenty-two percent (22%) of the papers confirmed the existence of politics within universities and faculties. For instance, with the high demand for data scientists, there is a risk of faculties losing their students to the data science field of study. This could result in an over-population of data scientists who do not appreciate the importance of other disciplines (Baumer, 2015). Several cases have been reported where transversal competencies and skills are not considered of primary importance (Demchenko, Wiktorski, et al., 2019; Gkamas et al., 2019; Takemura, 2018). The conflict between IT specialists and domain experts is usually caused by incongruities in their respective skill sets, processes, and terminologies which become a problem when training students to become data scientists. No study made suggestions on how this can be addressed.

ANALYSIS OF DSE STAKEHOLDERS

Generally, stakeholders can affect or be affected by business practices or policies. These practices can be internal or external, have interests, and can play various roles in organizations. Considering the nature of data science, it is important to identify the key stakeholders who can stand together to build DSE. Figure 11 shows the number of papers and their focus on different stakeholders.

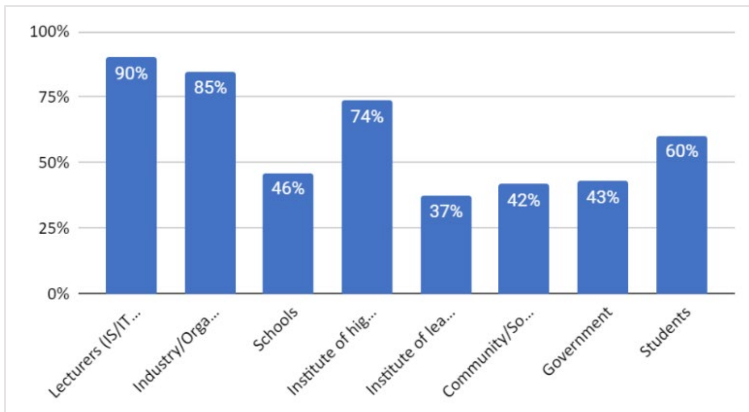

Figure 11. Article distribution per DSE stakeholders

It is observed from Figure 11 that each paper had more than one stakeholder representation, with lecturers having the highest number of representations (90%) followed by industry/organization (85%). Public institutes of higher learning were mentioned in 74% of the papers, while citations of private institutions of learning and schools were significantly lower at 37% of papers and 46% of the papers, respectively. In addition, students, government, and community were mentioned respectively in 60%, 43%, and 42% of the papers. The article distribution by DSE stakeholders shows a high interest in data science programs interest coming from different stakeholders, and thus suggest the importance of investigating and understanding the role of each stakeholder in DSE to maintain the transdisciplinary status.

DISCUSSION

DSE is a growing academic area that is not being explored, especially in developing countries. Many developing countries, particularly in Africa, face various challenges that can put them at a disadvantage in the global economy. Poor infrastructure, internet connectivity, and affordability can make it difficult for businesses to operate efficiently and for individuals to access education and training opportunities (Malaka & Brown, 2015). Additionally, the absence of skilled employees in key areas like data science can limit a country's ability to innovate and compete in the global marketplace. Addressing these challenges requires a multi-faceted approach that includes investments in infrastructure, education and training programs, and policies that encourage economic growth and innovation.

With the little research that has been conducted, case studies are used to investigate DSE, often for an in-depth examination of a particular instance of DSE. The majority of the reviewed case studies focus on undergraduate programs, intending to redesign the current computer science and statistics curriculum to create programs in data science. Other research methods such as experimental studies, interviews, and face-by-depth information collection can be used to assess the effectiveness of different DSE interventions and to collect in-between DSE students' experiences. Different research methods are needed to explore different contexts of DSE.

The high number of studies on undergraduate-level programs could perhaps be resulting from data science undergraduate degrees being based on existing curricula. Nonetheless, undergraduate programs provide a solid ground for complex data science concepts (X. Li et al., 2019). There is also an opportunity for the integration of DSE at the foundational level. Countries in Europe and the Middle East are also in favor of this (Mikroyannidis et al., 2018; Takemura, 2018). This aim is to allow learners to develop and grasp the soft and cognitive skills that students need as they advance their careers in the data science field. Other scholars argue for postgraduate DSE qualifications (Cao, 2019; Hosack & Sagers, 2015; Paul & Aithal, 2018) noting the importance of the research component and advanced skills (Hassan & Liu, 2020; Shamir, 2020). Where there are no clear learning outcomes for each level of learning, a framework is needed to guide the structuring of programs, then the curriculum designers can decide on what skills need to be attained at a specific level. This is to further avoid overlaps. There is also a suggestion for DSE short learning programs to improve proficiency and accommodate new developments (Attwood et al., 2019; Garmire et al., 2017; Otero et al., 2014). These may include micro-credentials; however, the concept is still new and in need of proper conceptualization for effective usage. There is also no evidence of a framework that guides the structuring and development of these programs.

While multidisciplinarity is key in DSE (Twinomurinzi et al., 2022), the learning programs often focus on scientific domains (such as computer science and statistics) without looking at domain-specific areas like medicine, and finance among others. These sentiments have been shared by a number of scholars (Bohler et al., 2017; Schwab-McCoy et al., 2021). The inclusion of science and non-science disciplines is crucial to offer a balanced data science program. In addition, students in transdisciplinary programs need to be provided with opportunities to work together and gain knowledge from peers and professionals from various professions. This helps students develop a broader perspective and improves their capacity to collaborate across disciplines. There are a few initiatives that present such opportunities such as datathons and hackathons (Huppenkothen et al., 2018).

While public institutions have been taking the lead in data science offerings, the industry is not exploring data science programs. Many industries are looking into hiring candidates that already have data science skills rather than developing the skill in-house. Based on unique business needs, it is necessary to understand the influence industry has on data science programs, and how the industry can collaborate with other stakeholders in DSE. In-house training or micro-credentials can typically be tailored to the specific needs of the business and can be an effective way for employees to gain practical experience in data science while working on real-world problems (Msweli et al., 2022). When selecting a data science learning program, individuals consider the factors such as the program's cost, duration, and content, as well as the reputation of the provider and the availability of job placement services. Understanding the purpose of teaching data science and the intended audience is important.

The transdisciplinary nature expected in DSE has been ignored for the more technical component. Yet, in reality, these aspects are becoming much more accessible while the "business aspects" are what require a great deal of adaptation (Bohler et al., 2017). In the context of teaching data science, the CRISP-DM framework can be effectively used to give students an organized method of approaching data analysis (Heinemann et al., 2018). It is important to establish how CRISP-DM phases can be incorporated into a data science curriculum. For example, instructors can offer direction and assistance to students at any point in the process to help them comprehend the significance of each phase and how they all work together to generate insightful or accurate forecasts. DSE can be organized and allow for transdisciplinary inclusion of the non-technical aspects of data science by adopting the CRISP-DM framework into training and teaching pedagogies.

With regard to teaching data science, it is not clear which pedagogies are suitable for this field, especially the pedagogies that embrace transdisciplinary learning. As an emerging discipline, there is still a debate as to what content needs to be presented and how it should be presented (Cao, 2017; Shulman, 1986). Considering that data science is presented to a diverse group of students, teaching practices need to consider the targeted audience and their background. Essentially, technological, pedagogical, and content knowledge is necessary to understand how teaching practices influence the way students perceive DSE (Gudmundsdottir & Shulman, 1987). In addition, transdisciplinary learning needs to be encouraged together with additional teaching resources that may support DSE (Schwab-McCoy et al., 2021).

It is clear that DSE inherits some challenges from other disciplines especially those within STEM (Twinomurinzi et al., 2022). Below is a summary of challenges that need to be addressed as part of supporting data skills supply:

- *Absence of policy on resource and data sharing.* Ethics and privacy issues are some of the barriers to data sharing. Even though these issues exist, the lack of awareness of data science benefits especially among government makes it difficult for them to see the need for policies that support data sharing, in particular the public data. Data science, being an emerging discipline, availability of resources is a challenge. This includes teaching resources (i.e., learning content and qualified instructors). Since data science seems to be more technical and complex, it requires qualified and experienced human resources to teach in this field. As a new discipline, very few qualified individuals can teach data science concepts (Msweli, 2023). Resource sharing may be one of the solutions, however, it can only be achieved if there is an agreement among key stakeholders.
- *Lack of transdisciplinary teaching pedagogies.* New tools are continuously being developed to transform the data science landscape. Accordingly, data science teaching practices need to be reimagined. Acquiring data science skills needs to be supported by teaching practices that encourage continuous learning. Little knowledge is available on how this can be achieved. However, instructors in this field should have pedagogical content knowledge (Mike, 2020; Msweli, 2023).
- *Teaching diverse audiences.* Currently, DSE attracts students from different backgrounds, and preparing data science classes needs to consider these differences, particularly for students with minimal cognitive skills. In the discipline of data science, cognitive abilities including critical thinking, problem-solving, and decision making are crucial for success (Demchenko, Comminiello, & Reali, 2019). However, it is common for data science students to be lacking in these abilities, especially if they are new to the program. Despite their background, the student should be provided with hands-on experience that targets data analysis and visualization, exposure to real-world problems, and training in critical thinking and problem-solving. This will help them become effective contributors to the growing field of data science.
- *Standardization and inconsistencies are critical issues in DSE.* The lack of recognized standards for DSE can result in variations in the caliber and scope of data science programs at various learning institutions. Absence of a professional advisory board or accrediting body for data science programs it is difficult to say which disciplines are underrepresented or overrepresented (Schwab-McCoy et al., 2021). Establishing standards or guidelines for data science curricula can give institutions a framework to work within when creating their data science programs.

Data science is a transdisciplinary field that combines expertise from various areas such as statistics, mathematics, computer science, and domain-specific knowledge. Data analytics is also applied to various business and non-business domains (Bohler et al., 2017). Key stakeholders need to work together in building DSE. Establishing a solid ecosystem that supports both the technical and non-technical aspects of DSE is necessary. There is very little literature that focuses on DSE, particularly on the potential influence that different stakeholders may have on democratizing DSE, and data policy.

Conclusion, Implications, Limitations, and Areas for Further Research

This paper presents a scoping review of the status of DSE research, and the selected papers were classified and coded using a classification coding framework. The development of the data science field has prompted academia to see prospects of how to introduce different DSE programs to support the training of data scientists. Despite the growth in data science programs some gaps need to be investigated, and research into DSE is not advancing at the required pace.

The results reveal an emerging influential field that is fragmented. The fragmentation lies in the inconsistencies of DSE programs, types of programs, and teaching pedagogies. The multidisciplinarity of data science, much like information systems, makes it challenging to have a consistent curriculum. The information systems field has managed to build professional and academic bodies that have enabled it to have fairly standard curricula. We recommend a transdisciplinary professional body to guide curricula in data science. There are some which currently exist, but these mainly focus on STEM at the expense of non-STEM disciplines. The professional body would also assist with other important aspects such as naming conventions in data science because some areas of the discipline employ the same principles but use different names which is confusing for emerging data scientists.

The rapid change of technology today requires flexible curricula which therefore influences the pedagogies adopted in DSE. We found that project-based pedagogy is the dominant pedagogy in DSE, but we recommend a combination of pedagogies because of the multidisciplinary nature of the field. There have been some developments in teaching strategies and tools that improve the teaching of STEM subjects such as gamification and metaverse which have been shown to improve science education (Hee et al., 2016). These are some strategies that may be considered for DSE.

A pertinent question also remains about the regions that were noted as having very little or no investment in DSE research – what may be the implications of this on skills availability, potential brain drain, or opportunities for skills development?

We also suggest that there is a need for more research to be conducted on DSE as the main theme, with various research methodologies such as experiments, action research, ethnography, and design science being adopted. Scholars need to establish how they can apply different theories and philosophies when researching DSE. Research coalitions between countries, industry, and academia are also an important step for future studies in DSE to build the knowledge base and reference repository. Furthermore, an opportunity exists to investigate the data science skills and competencies applicable in each sector. Industry practitioners within various sectors can contribute by serving as advisory or review boards for academic institutions. This will offer a better understanding of the industry needs especially those in the non-STEM domains. Working with various stakeholders and understanding each stakeholder's role can shape the DSE ecosystem that can be shared globally to grow data science. The study identified a lack of balance concerning the inclusion of data science concepts. Concepts within STEM are put at the forefront, while research on business-related applications of data science is limited. Essentially, there is a need for researchers to compile guiding principles or develop frameworks that will guide how each element contributes to data science and how to ensure a balance of these across DSE programs.

DSE needs to serve various business practices and simulate CRISP-DM. We, therefore, recommend CRISP-DM as a framework to adopt collaborative pedagogies to teach DS. This research implies that it is important for academia, policymakers, and data science content developers to work closely with organizations to understand their needs. The primary issue is that the nature of data is diverse and changes at a rapid rate, thus demanding continuous (up)skilling. Essentially, academic institutions need to be up to date with new developments, evolving data, and organizational needs. Industry practitioners can offer insights based on their experience in the field.

This work provided a systematic and in-depth analysis of the existing literature on DSE, offering valuable insights into best practices, specifically highlighting the CRISP-DM framework and its significance in guiding data analysis and problem-solving in various domains. With that being said, this study contributes to the growing literature on DSE. The identification of challenges in DSE is a step towards building learning programs that are fit for purpose and address various stakeholders' needs. This paves the way for future research to understand which programs can provide current and future data scientists the skills and competencies relevant to societal needs.

Areas for Further Research

The study found that there are a number of research opportunities that can be explored to improve the implementation of DSE. Below are some of the questions proposed for future research:

Research global representation

a. How can DSE research be promoted in developing countries?
b. How can cross-continental DSE knowledge sharing be implemented?

Research methodology

a. How can multiple methods be incorporated into DSE research?

Levels of qualification

a. What is the impact of DSE offered as short learning programs?
b. How can DSE be introduced at pre-tertiary levels?

Transdisciplinary teaching pedagogy

a. How CRISP-DM can be integrated into collaborative pedagogies to provide fully comprehensive DS curricula?

Collaboration

a. What is the impact of DSE programs that are jointly developed between academics and practice?
b. How can collaboration be fostered across the disparate disciplines of DSE?
c. How can industry/practitioners be encouraged to share datasets for DSE?
d. What role does government policy play in opening data for DSE?

DSE curriculum and governance

a. How can we conceptualize an effective DSE curriculum for higher education?
b. What experiences or preparation do lecturers need for teaching and learning in DSE?
c. What are the elements of a sustainable DSE ecosystem?
d. What would a DSE accreditation framework look like?

The disconnect between practical application and data science learning material

a. How can DSE meet the needs of organizations and society at large?
b. How can we equip data scientists with the skills and tools for reasoning with various types of data?

Limitations

This study was limited to DSE research published between 2010 and 2021. The search was limited to the following databases: Google Scholar, IEEE Xplore, ACM Digital Library, ScienceDirect, Scopus, and a Basket of eight IS Journals. The study was initiated from an information systems perspective and as such databases focusing on psychology and education reviews were not included owing to the scope and target audience of the paper.

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APPENDIX A: CLASSIFICATION CODING FRAMEWORK

(Appendix A can also be downloaded from https://bit.ly/DSECodingFramework

Theme	Description (initial coding framework)	Code
Continent (Origin)	Africa	1A
	Asia	1B
	Australia	1C
	Europe	1D
	Middle East	1E
	North America	1F
	South America	1G
	Not Specified	1H
Level (or type) of Qualification	Peer learning (i.e., outreach programs, hackathons, datathons, and bootcamps)	2A
	MOOCs and short learning programs	2B
	Micro-credentials, digital badges (badging system, digital platforms)	2C
	Undergraduate programs (degrees, diplomas, certificates)	2D
	Postgraduate (honors, masters and doctoral)	2E
	School education (i.e., primary, secondary)	2F
	Not specified	2G
Discipline-specific (Data Science Element)	Statistics/Mathematics	3A
	Computer science	3B
	Engineering	3C
	Non-science domain (non-STEM)	3D
	Data science	3E
	Not specified	3F
Data Science Education Provider	Public institutions of learning (universities, colleges, vocational education, and training)	4A
	Private institution	4B
	Industry/Organization	4C
	Collaborated	4D
	Not specified	4E
Data Science Context (using CRISP-DM)	Business requirement/understanding	5A
	Data understanding	5B
	Data preparation	5C
	Modeling	5D
	Evaluation	5E
	Deployment	5F
	Full data science lifecycle	5G
	Not specified	5H

Theme	Description (initial coding framework)	Code
Teaching Strategies	Use of technology (collaboration using digital platforms (apps), social media, or other digital communities)	6A
	Teacher-led (direct instruction)	6B
	Students-led learning/Game-based learning (extension of formal learning e.g., hackathons, game-based/competitions, community-driven)	6C
	Flipped classrooms (pre-recorded videos)	6D
	Personalized learning	6E
	Inquiry-based learning	6F
	Project-based learning	6G
	Competency-based learning	6H
	Not specified/other	6I
Opportunities/ Recommendations	Government involvement (policy, funding model, accreditation, open data)	7A
	Collaboration between university faculties (to maintain the multi-disciplinary nature of data science)	7B
	Industry involvement (live data/modern data streams/data expo, co-develop courses)	7C
	Professional advancement	7D
	Secondary school curriculum	7E
	Improve skills at schools and tertiary level/Capacity building (lecturers and school teachers)	7F
	Establish a data science governing body/Committee	7G
	Learning paths for data science	7H
	Integrated digital platforms (learning platforms/curriculum systems)	7I
Challenges	Pedagogy (teaching approaches)	8A
	Inadequate curriculum (e.g., aata ethics, business understanding, deployment)	8B
	Cognition (challenging concepts, i.e., statistics, programming)	8C
	Data science program structure	8D
	Data science tools (model misuse, misinterpretation of models)	8E
	University policies (regulatory frameworks across different disciplines, e.g., student recruitment and enrolment, limited resources)	8F
	Naming regimes	8G
	Assessment (assessing student achievement)	8H
	A disconnect between industry practice and data science learning material	8I
	Challenges of finding organizations willing to participate	8J
	Accreditation issues	8K
	Not specified	8L

Theme	Description (initial coding framework)	Code
Theory	Theory driven	9A
	No theory guiding the study	9B
Philosophy	Positivism	10A
	Interpretivism	10B
	Pragmatism	10C
	Critical realism	10D
	Not specified	10E
Research Method (Oates, 2006)	Experiment	11A
	Survey	11B
	Action research	11C
	Ethnography	11D
	Case studies	11E
	Design and creation (design science)	11F
	Not specified	11G
Data Science Education Stakeholders	Lecturers (IS/IT, mathematics/statistics, engineering, domain/business)	12A
	Industry/organizations (live data/modern data streams/data expo, internships)	12B
	Schools	12C
	Institute of higher learning – public	12D
	Institute of learning – private	12E
	Community/society/alumni (e.g., outreach programs)	12F
	Government	12G
	Students	12H

APPENDIX B: CORRELATIONAL ANALYSIS

(Appendix B is a spreadsheet that can be downloaded from this papers' publication page. It can also be downloaded from https://bit.ly/DSECorrelationalanalysis)

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DID ONLINE EDUCATION EXACERBATE CONTRACT CHEATING DURING COVID19 IN CHINA? EVIDENCE FROM SINA WEIBO

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ABSTRACT

Aim/Purpose	The purpose of this study is to explore the correlation between contract cheating and online education in China, which has become a major concern due to the extensive promotion of online education worldwide amid the COVID-19 pandemic.
Background	Contract cheating, also known as academic ghostwriting, refers to the act of students outsourcing academic assignments to third parties, who complete the work on their behalf. With the development of online education, the incidence of contract cheating is rising progressively. Whilst numerous scholars have conducted extensive research on the causes, prevention, and handling of contract cheating, the issue persists and needs further localized understanding.
Methodology	This study employs a mixed-methods approach. First, textual data on Sina Weibo, a popular Chinese social media platform, is collected and analyzed using VOSviewer and NVivo12 software. Field observation methods are also utilized for theme analysis and sentiment analysis. Second, the theoretical framework of organizational theory is applied to explain the impact of different modes of online education implementation on contract cheating. Finally, based on the findings, possible solutions to mitigate contract cheating are proposed.

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Contribution	This study contributes to the literature by providing a theoretical framework to explain the relationship between online education and contract cheating in China. The study's findings highlight the importance of the mode of online education implementation when addressing contract cheating.
Findings	This study finds that online education does exacerbate contract cheating in China, and the extent of this phenomenon varies depending on the mode of online education implementation. This study also identifies the lack of academic integrity education and supervision as a major factor contributing to contract cheating.
Recommendations for Practitioners	Reducing the costs of educational organizations in combating cheating through institutional arrangements, such as establishing effective channels of communication between teachers and schools and controlling teachers' workload outside of their primary responsibilities, can help curb contract cheating.
Recommendations for Researchers	Both history and reality have demonstrated that possible solutions cannot rely solely on new technologies or single institutional arrangements. Contract cheating is essentially an unethical means of competing for scarce resources, and as long as resources remain scarce, this phenomenon will persist.
Impact on Society	As a social phenomenon, contract cheating cannot be completely eradicated through top-down policy enforcement.
Future Research	The stringent enforcement against contract cheating also involves the education regulatory and judicial departments, and their relationship is worthy of future research.
Keywords	contract cheating, online education, textual analysis, organizational approach, field observation

INTRODUCTION

There are several forms of academic dishonesty that can occur in learning environments, including contract cheating, plagiarism, cheating on exams, fabrication, ghostwriting, collusion, multiple submissions, and unauthorized assistance. Comparing the various forms of academic dishonesty across different countries is an intriguing topic (Ahsan et al., 2021). Nonetheless, this article focuses primarily on examining the prevalence and implications of contract cheating within the academic landscape of China.

Contract cheating, also known as academic ghostwriting, refers to the act of students outsourcing academic assignments to third parties, who complete the work on their behalf (Clarke & Lancaster, 2013). With the development of online education, the incidence of contract cheating is rising progressively (Lancaster, 2019). Numerous scholars have conducted extensive research on the causes, prevention, and handling of contract cheating (Amigud, 2019; Amigud & Dawson, 2020; Awdry & Newton, 2019; Karasavvidis, 2010; Medway et al., 2018; Newton, 2018). For instance, to prevent contract cheating, some scholars suggest strengthening students' academic integrity education, adopting technological means for detection, increasing the uniqueness of assignments, and establishing strict management systems (Newton & Lang, 2016).

Contract cheating in ancient China was also known as "qiangti," which was first mentioned in historical records about the imperial examination system during the Tang Dynasty. The Chinese imperial examination system, or keju, was a highly esteemed system of selecting officials based on merit rather than on social status or connections. However, with such high stakes involved in passing the exams, it was not uncommon for candidates to engage in cheating practices. The government also issued severe punishments for those caught cheating, such as exile or execution. Despite these efforts, contract cheating continued to be a persistent problem throughout the history of the imperial examination system. The system was abolished in 1905 but contract cheating has continued to exist in modern times.

The modern Chinese national movement and state-building have transformed several features and contents of *the hybrid universalist imperial system* of the 19th century into *the organizational structure of the ethnic group and state* (Hui & Huters, 2006). Organizational structure is a crucial factor that influences organizational behavior. Whether it is the promotion of online education or the crackdown on contract cheating in China, these efforts take place within *the framework of the Chinese educational organization* (see the Appendix for an explanation of these italicized terms). Therefore, examining the relationship between contract cheating and online education from an organizational perspective would be an intriguing endeavor.

The contribution of this study lies in the combination of big data analysis from Sina Weibo and field observations to investigate the changes in contract cheating within the organizational structure of education in China during the COVID-19 pandemic. By exploring the mechanism through which online education influences contract cheating, the study sheds light on the organizational logic behind contract cheating, providing new insights for the prevention and control of such behavior.

The rest of the paper is organized as follows. In the following section, the literature will be reviewed. Then, the authors will present the research question and methodology. After the methodology section, we will discuss the results. Finally, we will outline the research contributions and limitations.

Literature Review

Currently, one of the most serious threats to academic integrity is posed by contract cheating (Foltýnek & Kralikova, 2018). By outsourcing academic work to a third party, students commit contract cheating and violate academic integrity (Stoesz & Los, 2019). Studies have shown that contract cheating is a widespread problem across different educational levels and disciplines. A survey conducted by Clarke and Lancaster (2013) found that one in seven students had paid someone else to complete an assignment for them. Similarly, a study by Newton and Lang (2016) found that 15.7% of surveyed students had engaged in contract cheating, and 7.9% had done so in the past year. Contract cheating has also been reported in postgraduate and professional programs, such as law and medicine (Bretag, 2018).

With the rise of online education during the COVID-19 pandemic, there have been concerns about the potential increase in contract cheating (Tremayne & Curtis, 2020; Yorke et al., 2020). Research has shown that contract cheating is more prevalent in online courses than in face-to-face courses (Lancaster, 2020). The anonymity and convenience of online courses may make it easier for students to engage in contract cheating. In addition, online courses often rely on objective assessments, such as multiple-choice exams, which can be more easily outsourced to third-party providers. A study by Newton and Lang (2016) found that contract cheating increased by 15.7% during the pandemic. Also, the study found that the use of online proctoring tools did not deter contract cheating (Rowland et al., 2018).

Several factors have been identified as contributing to contract cheating in online education. One factor is the lack of face-to-face interaction between students and instructors. This can lead to a lack of personal accountability and increased anonymity, which may make it easier for students to engage in contract cheating (Harper et al., 2019).

Another factor is the pressure that students may feel to perform well in online courses. With the increase in online education during the COVID-19 pandemic, there has been a significant increase in the number of students taking online courses. This may create a competitive environment in which students feel pressure to perform well, even if it means engaging in contract cheating (Clarke & Lancaster, 2013; Lancaster & Clarke, 2016).

Several strategies have been proposed to prevent contract cheating in online education. One strategy is to design assessments that are difficult to outsource to third-party providers. For example, assessments that require higher-order thinking skills, such as critical thinking and problem-solving, may be more difficult to outsource (Harper et al., 2019).

Another strategy is to use technology to detect contract cheating. Online proctoring tools, plagiarism detection software, and machine learning algorithms are examples of technologies that can be used to detect contract cheating (Newton & Lang, 2016). However, it is important to note that these technologies are not foolproof and may have limitations.

The existing research on the relationship between contract cheating and online education during COVID-19 provides some important insights, but there are also limitations that should be considered. Most of the research is conducted on students in Australia, the USA, the UK, and Czechia, but there is no research conducted in this area in China.

Most of the research conducted in this area is based on surveys and interviews with limited sample size. This may limit the generalizability of the findings and make it difficult to draw firm conclusions about the prevalence of contract cheating in online education.

The dominant methodology in this field is empirical studies and theory-based research is scarce.

RESEARCH QUESTION

With the outbreak of the COVID-19 pandemic, many schools in China have been forced to adopt online education. The study aims to answer this research question:

What are the contributing factors to contracting cheating in tertiary education in China?

- Has online education made contract cheating more prevalent in China?
- What lessons can we draw from the legacy of the imperial examination system in China to address contract cheating?

METHODOLOGY

Organizational theory is a field of study within management and sociology that focuses on understanding and explaining how organizations function, operate, and interact with their internal and external environments. This theory encompasses various theoretical perspectives, frameworks, and concepts that aim to analyze and interpret the behavior, structure, and dynamics of organizations. This theory helps to explain the complexities of organizations and provides frameworks for understanding organizational behavior, effectiveness, and performance. This theory is relevant across various sectors, including business, government, non-profit organizations, and educational institutions. Exploring the state and society within the framework of organizational theory helps us understand the role that educational institutions play as social organizations.

The operation process of a country, its ability and method to solve problems, the choice of coping with crises, and the relationship between the state and society, are all based on a series of institutional arrangements. These stable institutional arrangements shape the ways and methods of problem-solving, induce corresponding micro-behaviors, and largely determine the trajectory, choices, and consequences of national governance (Zhou, 2022). This description is also very appropriate for understanding the phenomenon of contract cheating during the COVID-19 pandemic in China.

Organizational theory can facilitate people's comprehension of the phenomenon of contract cheating, but it necessitates substantial support from big data. Sina Weibo data from 2019-2022 is used to analyze the intrinsic connections and mechanisms behind online education and contract cheating from micro to macro perspectives. Effective measures to solve contract cheating are sought from organizational theory.

DATA COLLECTION

With a self-built web program, the authors commenced their search using the following key terms: “online education,” “online learning,” “contract cheating,” and “exam cheating.” Sina Weibo posts from the year 2019 to 2022 with the above terms present in their title and content were selected. We obtained 58,194 Weibo posts about contract cheating and 11,8824 Weibo posts about online education.

DATA PROCESSING

To process the collected data, the authors employed Python programming for data cleansing. After that, the redundant and insufficient data was eliminated. To perform text analysis, we used Python and LDA algorithms. While Python is a powerful language for text analysis, it does have some weaknesses. Text analysis can be intensive computationally, and Python may not always be the fastest option for large datasets. While LDA is a popular and effective algorithm for topic modeling, it has its limitations, such as difficulty handling short texts and a tendency to generate similar or overlapping topics. Despite the existence of numerous LDA enhancement algorithms, for quantitative research on social issues, it is desirable to employ consistent standards as much as possible. This constitutes a limitation of Python, but a strength of NVivo and VOSviewer. So, the authors employed NVivo for sentiment analysis. Before conducting the sentiment analysis, we imported the contract cheating data into the stop word library and consolidated synonyms. We then performed word segmentation to divide each post into several keywords. Finally, we employed VOSviewer to perform topic analysis. The ultimate outcome is the co-occurrence network of keywords for each year which assists in identifying the themes and emotions implied in the posts.

RESULTS

The groupings of the keywords in 2019 led to three clusters, which are graphically presented in a network diagram (Figure 1). The themes within each cluster can be regarded as fundamental aspects of contract cheating.

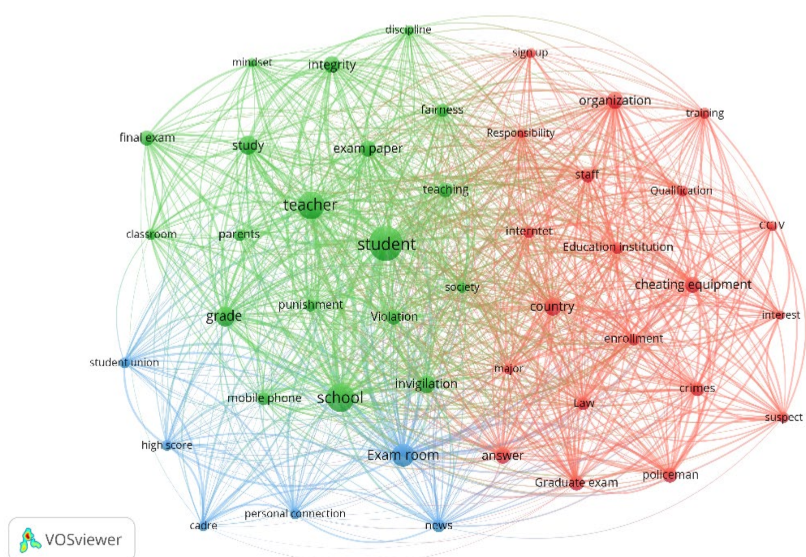

Figure 1. Co-occurrence Network of contract cheating in 2019

In a textual co-occurrence network, each node represents a keyword, and the connections between nodes represent the relationships between keywords: larger nodes indicate higher frequencies of the corresponding keywords, while thicker connections indicate higher frequencies of co-occurrence between two keywords. The highest co-occurrence frequency of "school," "teacher," "student," and other key terms are evident (Figure 1), suggesting a significant avenue for research potentially.

The cross-year variations in the co-occurrence frequency of keywords in co-occurrence networks may contain rich information. For instance, the relative increase in the co-occurrence frequency of "Cheating equipment" and other keywords in 2020 (Figure 2) compared to 2019 may be due to the outbreak of the COVID-19 pandemic, which led to the implementation of online education and exams in many Chinese schools. This resulted in increased public attention to contract cheating, indicating the spreading of contract cheating to a broader range. With the easing of the pandemic in 2021 (Figure 3), the frequency decreased relative to 2020, while it significantly increased again with the resurgence of the pandemic in 2022. In contrast, the co-occurrence frequency of "Fairness" with other keywords remained relatively stable across the years, indicating that fairness is a persistent concern of the public.

The evolutionary trajectory of the overall structure of co-occurrence networks may also contain rich research value. Although there were some differences in the co-occurrence networks between 2019 and 2022 (Figure 4), the three major themes, namely educational implementing agencies (green nodes), educational supervisory departments (blue nodes), and judicial departments (red nodes), were clearly distinguished. (The yellow nodes in the Figure 3 represent keywords that could not be classified into any specific cluster.) The co-occurrence frequency of most keywords within each cluster evolved. However, within the educational implementing agencies cluster, the keywords "schools," "teachers," and "students" remained the most important and stable, indicating that the public is not only concerned with contract cheating but also highly attentive to these themes. The relationships among schools, teachers, and students should be the starting point for researching contract cheating.

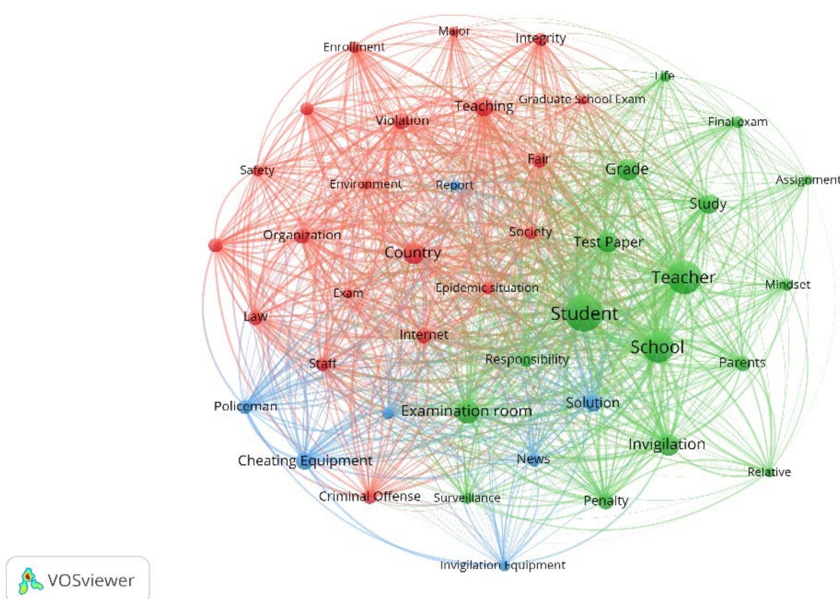

Figure 2. Co-occurrence Network of contract cheating in 2020

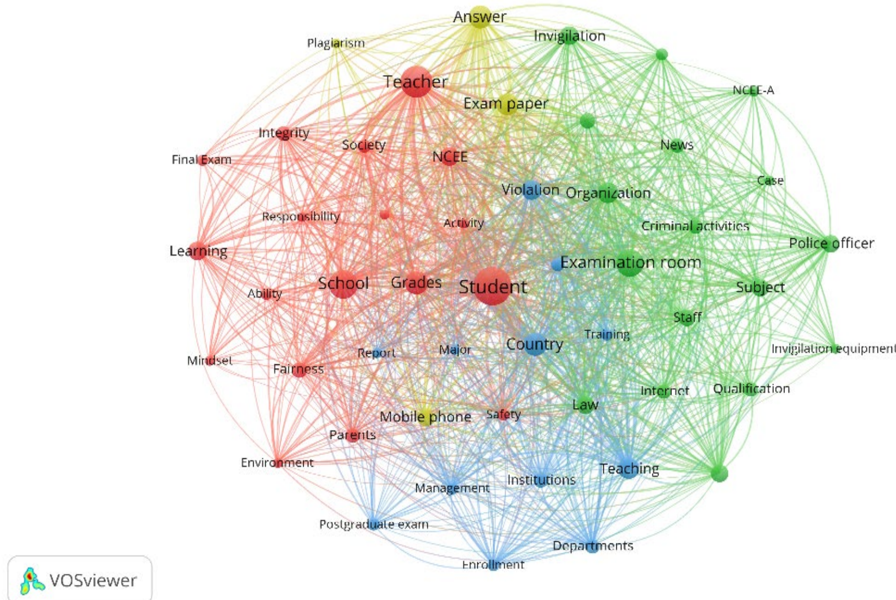

Figure 3. Co-occurrence Network of contract cheating in 2021

An organization is a system composed of interdependent parts that interact and engage in feedback mechanisms. The overall performance of an organization depends on the coordination and interaction among its individual parts (Zhou, 2022). We could conceptualize a co-occurrence network as an abstract organization. The relationships among important nodes in the co-occurrence network reflect the reality of the education field in China (Figure 4).

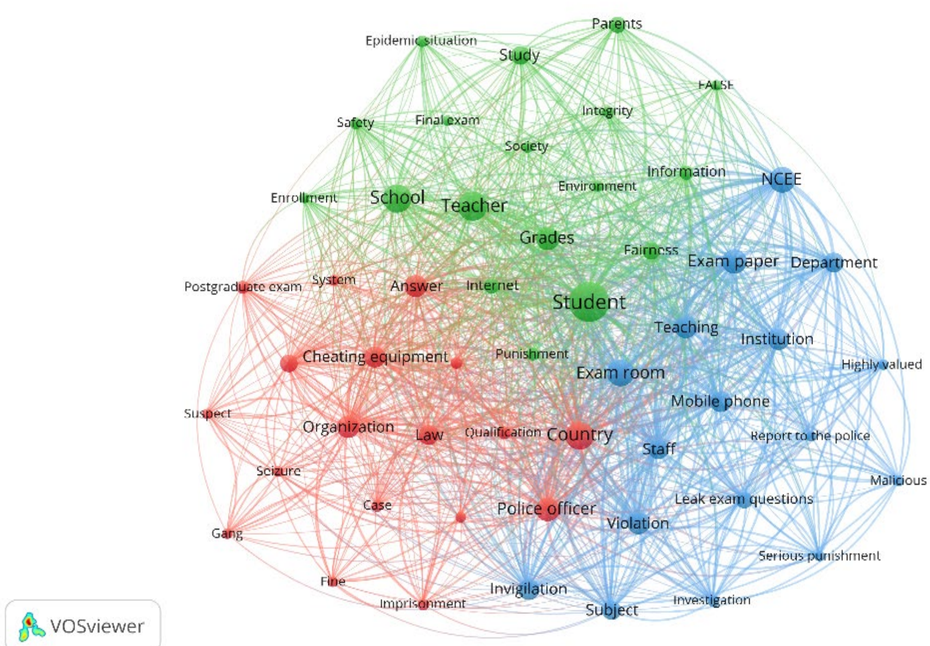

Figure 4. Co-occurrence Network of contract cheating in 2022

The Ministry of Education of China is the highest administrative body in the field of education, followed by the provincial education departments, municipal education bureaus, and county education bureaus. All levels and types of schools receive technical guidance and relevant instructions from the higher-level education administrative bodies, but their financial budgets are controlled by other government agencies. Teachers carry out teaching activities under the management and instructions of schools, but their staffing and promotion are controlled by other government agencies, and their income and professional titles are influenced by student and societal evaluations. This structure results in teachers facing conflicting demands from multiple directions, leading to conflicts between multiple goals.

The ambiguity of assessment methods and standards for teachers has always been a prominent characteristic of the education field, which is even more pronounced in the context of online education. For instance, the phenomenon of low student participation in the online education process could be attributed to various factors such as teacher responsibility or competency issues, lack of on-site supervision or psychological support for students, or technical malfunctions of network equipment. The multiple interpretative possibilities determined by people's interests or past experiences reflect the ambiguity of information, which in turn makes it difficult for monitoring and incentive measures designed to address the information asymmetry between schools and teachers to fully take effect. This implies that teachers possess more knowledge and technical processing capabilities than schools, and therefore gain certain advantages in negotiations concerning assessment standards, workload, and responsibility sharing. The technically stronger online education mode amplifies this advantage.

The Selection Between Regular and Mobilization Patterns

In the process of implementing online education, schools choose between two modes: mobilization mode and regular mode. Mobilization mode was chosen during the outbreak of the COVID-19 pandemic, while the regular mode is chosen before and after the outbreak subsides (Figure 5). In regular mode, online education is implemented through the established daily teaching rules and procedures, and the pressure on teachers is normal. In mobilization mode, the school promotes online education through high-pressure measures, injecting a large amount of attention and resources, including strict supervision mechanisms, intensive audits and inspections, and corresponding increased punitive measures, to convey higher credibility commitments or threat messages.

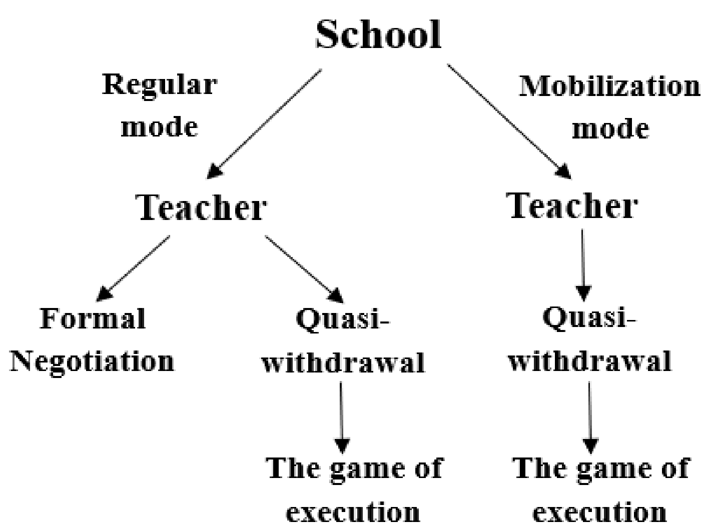

Figure 5. The game theory model of implementation patterns for online education

There is a rich organizational significance behind these two implementation modes. From the perspective of organizational analysis, in the regular mode, the implementation of work is established on daily procedures and corresponding organizational expectations, and members within the organization are in a loosely connected state, which leaves more space for negotiation processes between superior and subordinate departments. In contrast, the mobilization mode implies a high degree of top-down pressure, so that members within the organization are closely connected and efficient. However, the initiation and maintenance of the mobilization mode require injecting many resources (such as attention, extra resources, frequent checks, and interruptions or interference in other aspects of task deployment), which is costly and difficult to sustain in the long term. Therefore, the regular mode is the norm for organizational operation.

In response to the severe outbreak of COVID-19 in 2020 and 2022, online teaching mode was mandated at all levels of schools in China to control the spread of the pandemic. Schools and teachers devoted substantial resources to promoting online education and reported various data at high frequencies, yet insufficient investment was made in student supervision and interactive engagement. This has resulted in an upsurge of contract cheating among students, as indicated by the change in emotional proportion towards such behavior. Based on the observations of the authors, there appears to be a positive correlation between the severity of contract cheating and the intensity of negative emotions that the public harbors toward it. However, the incidence of contract cheating among students was mitigated in 2019 before the pandemic outbreak, and in 2021 when the pandemic was alleviated (Figure 6).

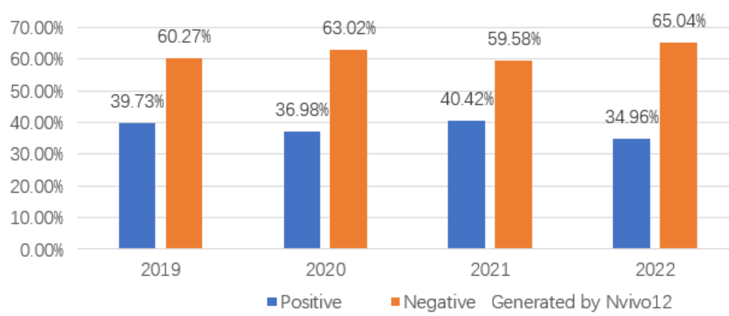

Figure 6. Changes in emotional inclination toward contract cheating from 2019-2022

The Teacher's Response: Two Coping Strategies and Corresponding Negotiation Games

In the hierarchical organizational structure, lower-level departments (the teacher) can engage in formal organizational procedures to negotiate with higher-level departments (the school) on issues related to online education, by presenting explanations, requests, or other types of solicitations to the school. The school will then provide feedback on these top-down requests through formal communication channels, and this type of interaction is referred to as "formal negotiation." Negotiations usually revolve around the evaluation standards of the implementation effectiveness of online education, sharing of responsibilities, and other related topics. The effectiveness of online education implementation typically also includes the handling of contract cheating.

The above-mentioned formal negotiation game is a common communication method between superior and subordinate departments in various types of hierarchical organizations. In general market negotiation games, either party can choose to withdraw from the negotiation. The party with the option to withdraw has a way out in case the negotiation fails, thus possessing stronger negotiation capabilities. However, the authors note that internal negotiation games within schools occur under the conditions of formal authoritative structures and bilateral monopolies, and neither party can choose to withdraw. This is especially true for teachers, who cannot refuse top-down command deployment and cannot choose to withdraw from the interaction with the school independently. Nevertheless, teachers have the option of "quasi-withdrawal." Quasi-withdrawal refers to a situation in which the agent is forced to accept the superior's command but withdraws covertly by means of non-cooperation in the subsequent execution process.

In the specific process of promoting online education, if schools choose to implement the regular pattern, teachers may be able to protect their own interests through formal negotiations. However, if schools choose to implement the mobilization pattern, teachers cannot resist, rebel, or negotiate through formal procedures openly, but must adopt informal and subtle resistance methods. The changes in the emotional proportion toward online education from 2019 to 2022 reflect this proposition (Figure 7).

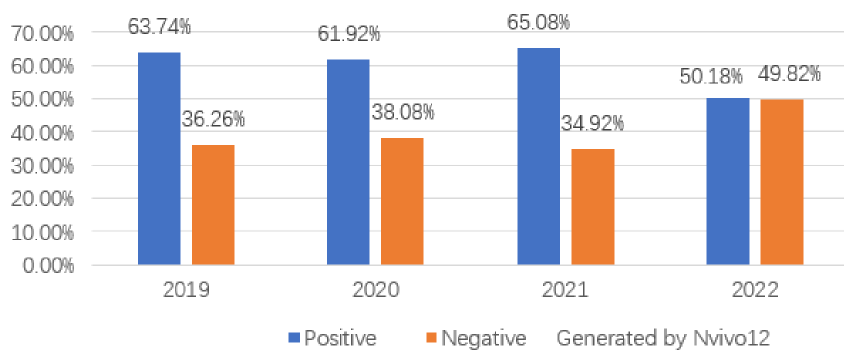

Figure 7. Changes in emotional inclination towards online education from 2019-2022

When the COVID-19 epidemic did not break out in 2019, the proportion of positive emotions toward online education among the public was 63.74%. This proportion decreased to 61.92% in 2020 due to the outbreak of the epidemic, possibly because some teachers adopted a "quasi withdrawal" strategy towards online education under a mobilization pattern. The change in this proportion in 2021, when the epidemic was under control, and in 2022 when the epidemic worsened, also followed the same pattern.

DISCUSSION

The purpose of selecting different implementation modes in schools is to send signals to teachers regarding the level of credibility commitment or threat intensity. The reasons for making specific choices may be internal or may come from external environments or crises. Undoubtedly, the selection of online education modes in various levels of schools in China during the COVID-19 pandemic originated from external factors. This section discusses the conditions under which teachers choose different coping strategies once a particular implementation mode has been selected by the school. Although some literature suggests that online education provides convenience for teachers in certain aspects, it also brings some new problems to their teaching activities. Through the analysis of the data on the relevant topics of online education and contract cheating on Sina Weibo from 2019 to 2022, the main problems can be summarized as follows:

- *The education of students with physiological or psychological disorders:* In face-to-face teaching, teachers can detect physiological or psychological abnormalities in students quickly and address them through immediate face-to-face communication. However, in online teaching, identifying such anomalies and implementing solutions is more challenging for teachers, who have fewer options and higher costs for addressing such issues.
- *The educational issue for students with inadequate Internet connectivity:* For students lacking necessary internet equipment and residing in areas with poor network coverage, certain technological

measures can alleviate the difficulties posed by these challenges. For instance, students in areas with weak Internet signals may opt for recorded lectures instead of live-streamed ones, although this could potentially result in a diminished educational experience and provoke complaints from both students and parents.

- *Education on cybersecurity and ethics:* The impact of open access to online content on education has long been a hotly debated issue of societal concern. This impact has been amplified in the context of online education, leading to cybersecurity and ethical issues. Teachers at the forefront of education are forced to dedicate a significant amount of time and energy to address these issues, in addition to their professional teaching duties, and must be prepared to provide psychological support to students and parents who may be affected by the pandemic.
- *The advancement of cheating methods:* Through data analysis, it has been found that "cheating tools" and "cheating devices" are the main keywords in relevant topics on Sina Weibo over the years. With the advancement of technology in contract cheating, it has become increasingly difficult to detect contract cheating by traditional means, especially in online education and its associated online assessment. This presents new challenges for teachers.

As can be seen from the above, online education puts higher demands on the learning and adaptability of teachers. To adapt to the new environment, teachers must quickly master numerous new skills and continuously update them, which increases the human cost of teachers greatly. Therefore, it is reasonable for teachers to have a sense of resistance toward online education.

When schools choose to implement online education in a regular mode, teachers can express their demands to the school and negotiate with the school on the execution details, standards, and resources required for online education. However, when schools choose to implement online education in a mobilization mode, it means that the school is implementing a higher intensity of credibility threat and creating a political environment with great pressure through a large-scale top-down campaign. In this situation, the space and flexibility for negotiation between teachers and the school are small. In a highly mobilized state, the risk of severe punishment for teachers who adopt behavior contrary to the school's is increased sharply. Therefore, the best strategy for teachers is to "quasi-withdraw" and carefully protect themselves in an unfavorable and high-pressure environment. This coping strategy postpones the interaction between schools and teachers in the process of executing games. Based on the analysis above, compared with the regular mode, teachers have less room for formal negotiations with schools on issues related to online education in the mobilization mode significantly. "Quasi-withdrawal" is the best response strategy for teachers. As the implementers of online education, teachers may leverage the asymmetry and ambiguity of information to gain more benefits in the game of implementation with schools. This has been demonstrated in the process of assessing teachers' performance in online education by schools prominently.

During the COVID-19 pandemic, despite various pressures, schools in China have achieved the normalization of assessing the process of online education, often with more detailed assessments than those for offline teaching. The game between schools as the assessors and teachers as the assessee is the main organizational process of assessment, which mainly involves information control and counter-control. Here, information refers to various assessment indicators in the process of online education, such as student online rates, average online duration, and frequency of online interactions between teachers and students. This information has asymmetric and ambiguous features. Asymmetry refers to the fact that teachers have more information than schools, while ambiguity refers to the fact that the same information can have multiple interpretations. Therefore, even if there are clear measurement standards for online education assessment indicators, the asymmetry and ambiguity of information may still hinder the collection of accurate information for the purpose of assessment. The purpose of school assessment is to collect accurate information about the operation of online education, while teachers may control and use the information for their own benefit strategically.

During the assessment process, schools have the authority to determine when and how to conduct assessments, which appears to be effective on the surface. For example, inspectors can enter web classrooms at irregular intervals to assess the effectiveness of teachers' classroom teaching, and a ranking system can be introduced to facilitate mutual assessment and competition among teachers. This should ensure the effective implementation of assessments in online education. However, the reality may not be so perfect.

Based on the authors' field observations, when faced with unsatisfactory data on student online attendance rates and duration, teachers may attribute it to technical malfunctions or student mishandling of network equipment. These factors are often difficult to verify afterward due to technical reasons or the high cost of verification. While schools assess teachers, they also must undergo assessments from higher education authorities. Furthermore, those responsible for assessing teachers are themselves subject to assessment, which restricts the operation of the school's assessment power.

In summary, while the mobilization pattern of operation allowed schools to implement online education quickly, it comes at a high cost. Even with substantial investments in resources, teachers may not necessarily comply fully with the school's requirements and may instead adopt a "quasi-withdrawal" strategy to carry out online teaching according to their own interests and intentions, potentially leading to relaxed supervision of contract cheating. From this perspective, the mobilization mode of operation cannot be the primary way for schools to promote online education. The fact that Chinese education authorities emphasized immediately that schools should not mandate comprehensive online teaching after the end of the COVID-19 pandemic in December 2022 indicates this point.

CONCLUSIONS

For over a thousand years, the rulers of ancient China have employed various methods to combat contract cheating, using top-down policies. However, this social phenomenon persists to this day. Like other policies in this ancient empire, the anti-cheating measures are executed by individuals within the organization, which inevitably involves a game of interests among different stakeholders within the empire. This game leads to deviations in the effectiveness and goals of policy implementation. Organizational theory can help in understanding the underlying logic of contract cheating for it can explore the formal and informal structures within an organization. In the context of educational institutions, understanding the hierarchical structure can shed light on the power dynamics that might influence contract cheating.

The main contribution of this study is that, based on the authors' field observations, the logic of contract cheating remains relevant in modern social networks and educational environments. Specifically, different implementation modes of online education have altered the costs and corresponding behaviors of teachers, resulting in various impacts on the prevalence of contract cheating. Therefore, as a social phenomenon, contract cheating cannot be completely eradicated through top-down policy enforcement. Both history and reality have demonstrated that possible solutions cannot rely solely on new technologies or single institutional arrangements. Contract cheating is essentially an unethical means of competing for scarce resources, and as long as resources remain scarce, this phenomenon will persist. However, reducing the costs of educational organizations in combating cheating through institutional arrangements, such as establishing effective channels of communication between teachers and schools and controlling teachers' workload outside of their primary responsibilities, can help curb contract cheating.

The main limitation of this study is that, due to length constraints, it mainly focuses on the game relationship between schools and teachers within the Chinese education implementation organization, and insufficiently explores the game relationship between teachers and students. The crackdown on cheating also involves the education regulatory and judicial departments; the relationship between these two departments regarding contract cheating is worthy of future research.

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APPENDIX – EXPLANATION OF TERMS

The hybrid universalist imperial system

In this system, the empire pursues a universalist ideology or set of values and seeks to impose it on other regions or ethnic groups. However, this system also incorporates other forms of governance and management to accommodate the characteristics of different regions and cultures.

The organizational structure of the ethnic group and state

This refers to the arrangement and functioning of interethnic relations, power distribution, political institutions, legal systems, and other aspects within a multiethnic country.

The framework of the Chinese educational organization

The Ministry of Education of China is the highest administrative body in the field of education, followed by the provincial education departments, municipal education bureaus, and county education bureaus. All levels and types of schools receive technical guidance and relevant instructions from the higher-level education administrative bodies, but their financial budgets are controlled by other government agencies.

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INTERNET OF THINGS (IOT) APPLICATIONS IN EDUCATION: BENEFITS AND IMPLEMENTATION CHALLENGES IN GHANAIAN TERTIARY INSTITUTIONS

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ABSTRACT

Aim/Purpose	The Internet of Things (IoT) application modules have covered diverse sectors, and the educational domain is no exception. In this survey, we discuss the specific application benefits of IoT in education and further examine implementation challenges in Ghanaian tertiary institutions.
Background	This survey examines pertinent applications for IoT benefits in education and offers present and future opportunities to enhance educational outcomes. The survey includes anticipated IoT technologies that will have a significant impact on education. Each module contains concise definitions accompanied by analysis and application-specific relevance.
Methodology	In order to accomplish the objectives of the survey, a search review was conducted across relevant databases, including Scopus, Hindawi, IEEE, MPDI, ScienceDirect, Informing Science Institute, Springer, and Wiley. In addition, a thorough search was carried out using Google Scholar to cover all relevant repositories. The phrases and keywords for the search were made up of five cate-

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	gories. The literature search resulted in 300 articles, of which 200 were considered relevant for the survey. Of the 200 articles, 95 of them shared common themes and discussed the same application integration and challenges.
Contribution	This paper discusses the revolution involving IoT deployments in education and covers many aspects of the educational domain.
Findings	IoT integration in education will transform Education 4.0 and improve learning outcomes significantly.
Recommendations for Practitioners	Educational institutions are to embrace IoT integrations even with the emerging Education 4.0 and Industry 4.0 use cases.
Recommendations for Researchers	Educational IoT is the next big thing and research directions on unique use cases for educational institutions are eminent with 5G and other disruptive technologies.
Impact on Society	Effective IoT implementation in education will positively affect all stakeholders in the educational ecosystem and create a society with much access to information, connectivity, and convenience.
Future Research	To survey the integration of blockchain-based IoT applications in education.
Keywords	Internet of Things, smart campus, intelligent objects, smart school, tertiary institutions

INTRODUCTION

The Internet of Things (IoT) revolution continues to be a buzzword in the twenty-first century, spanning numerous application sectors. Unlike decades ago, the connectivity of objects has proliferated rapidly and attracted various infrastructure supports from many nations. IoT has been defined as the network of physical objects fitted with sensors, software, and other technologies (Kumar et al., 2019). The numerous innovative and intelligent solutions IoT provides have rejuvenated the idea of total convenience of life to its primary beneficiary, the human being. IoT has evolved into a vast network of smart systems that have opened up new technological possibilities in every industry (Nord et al., 2019). Interoperability is one of the fundamental elements of the IoT that contributes to its growing popularity. Connected objects can gather and share data from their monitored environments with other devices and networks. Devices can now fulfil their duties with little or no need for human intervention as a result of the analysis and processing of data (Ali et al., 2019). It is not surprising that IoT continues to evolve as more and more devices are connected, resulting in more complex algorithms and higher levels of automation (Elijah et al., 2018). Since it can link to so many different "things", IoT has opened up many possibilities for individual users and large industries. According to the Ericsson Mobility Report (Ericsson, 2018), the number of connected devices will reach 22.3 billion by 2024, including 4.1 billion cellular IoT connections, 17.8 billion short-range IoT connections, and 4.5 billion wide-area IoT connections. The subsequent Ericsson Mobility Report (Ericsson, 2020), as indicated in Figure 1, anticipates an increase to 20.6 billion short-range IoT connections, 5.9 billion cellular IoT connections, and 6.3 billion wide-area IoT connections. This brings the total linked devices to 26.9 billion by 2026, up from 22.3 billion in 2024 and 12.6 billion in 2020. IoT's compound annual growth rate (CAGR) is 13% based on the growth forecasts.

The rise and application deployment of IoT devices has been thoroughly explored in several sectors. The IoT smart monitoring domains cover health, homes, transportation, grids, cities, agriculture, industries, and education (Jabbar et al., 2018). Home automation using IoT devices provides comfort, improves security, and makes home appliances more energy-efficient (Mocrii et al., 2018). Smart home deployments, safety, benefits, and challenges have been studied in depth (Cyril Jose & Malekian, 2015; Paul et al., 2018).

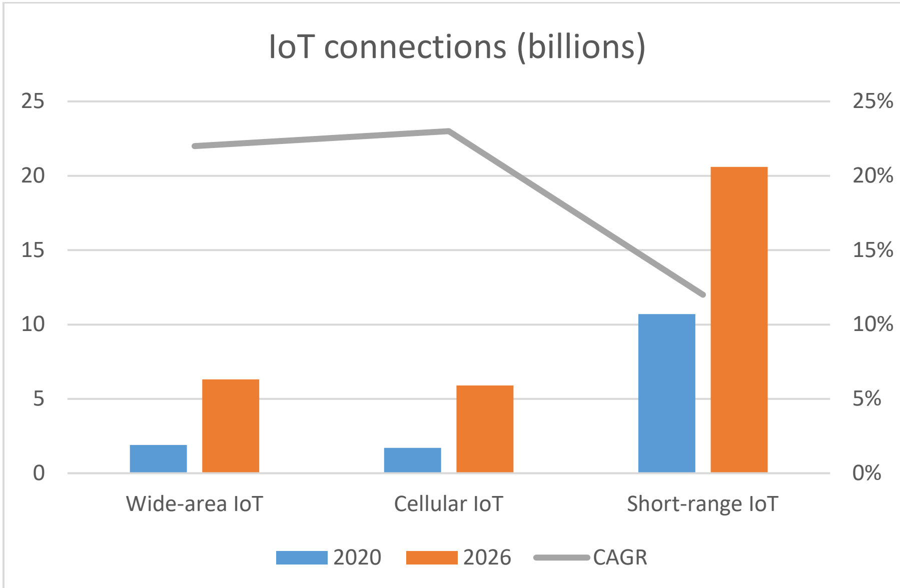

Figure 1. Ericsson Mobility Report (Ericsson, 2020)

Smart healthcare helps deliver quality healthcare and monitors patients' health information via wearable devices (M. Gupta et al., 2021). A considerable amount of research has provided solutions to the security lapses of IoT healthcare and advanced the healthcare sector with different architectures (Baker et al., 2017). Other specific benefits of IoT in agriculture, industry, transportation, and grids have been comprehensively studied with improvements in sector automation (Dambal et al., 2016; Ghasempour, 2019; Zantalis et al., 2019).

Recently, there has been a growing interest in IoT deployments in education. Such interests go beyond theoretical research to architecture developments and physical implementations. The fundamental objective of this survey is to discuss the applications of IoT in education, its benefits, and foreseeable challenges.

IoT has the potential to transform education with technological integrations that will increase the interconnectivity of divisions within academic institutions. Over the years, academics have undertaken substantial research on the desire for student performance improvement. Initially, teacher-centred pedagogy was the norm, with the instructor as the master of knowledge and the learner as the receiver (Serin, 2018). The behaviourist theory laid the foundation of teacher-centred pedagogy, which later received criticism in educational domains. Constructivism, a learner-centred theory, was then introduced. Constructivism is a pedagogy that enables learners to build representation and develop new knowledge rather than passively receiving information from their teachers (Feyzi Behnagh & Yasrebi, 2020). The constructivism model's pedagogical goals include student-centred learning, learner reflection, and diverse perspectives (Ekpenyong & Edokpolor, 2016). Collaborative pedagogy became widespread, based on interdependence or a joint intellectual focus where learners form groups and build learning strategies to complete tasks (Scager et al., 2016). Another popular learning philosophy is inquiry-based pedagogy, which encompasses constructivism and collaborative pedagogy, enabling learners to follow scientific methods and practices in constructing knowledge (Nunaki et al., 2019). The emergence of IoT in education will improve the various pedagogical philosophies. The IoT paradigm will redefine the teacher and learner, creating an intelligent campus hub that will improve educational outcomes significantly. The question, however, is whether countries and educational institutions are positioned economically and with policies to integrate IoT and take advantage of its numerous benefits.

Over the years, the Ghanaian government has strived to implement innovative policies to improve the quality of education at the pre-tertiary and tertiary levels. One major intervention was the Free Compulsory Universal Basic Education (FCUBE) Act of 1996, which increased enrolment rates average to 90% in 2017 at both the primary and junior high school levels (JHS) (Ministry of Education, 2017). At the senior high school (SHS) level, the government in 2017 replaced the progressively free SHS education policy with the free SHS policy, rendering SHS education completely free (Chanimbe & Dankwah, 2021; Ministry of Education, 2017). The tertiary level has its fair share of policies, including, converting polytechnics into technical universities, aggressively promoting science, technology, engineering, and mathematics (STEM) education, expanding access to technical, vocational, and agricultural education and training (TVAET), and a presidential assent Act in 2020 for the inauguration of the Ghana Tertiary Education Commission (GTEC) (Ministry of Education, 2017). GTEC exists primarily as an oversight agency in providing guiding policies for world-class tertiary education (Ghana Tertiary Education Commission, 2020).

Even though the Government has made progressive gains in education, educational institutions continue to suffer from severe infrastructure and technological deficiencies due to crippling economic downturns that have ripple effects on other important sectors of the economy (Arthur & Arthur, 2016). The damaging economic challenges, including debt overhang, high budget deficit, high inflation, cedi depreciation, low productivity, unstable power, and high unemployment, have been exacerbated further by the ravaging COVID-19 pandemic (Aduhene & Osei-Assibey, 2021; Ministry of Finance, 2022; Owusu-Manu et al., 2019). The drawn conclusion is that the implementation of immersive and interactive technologies in Ghanaian tertiary institutions has low priority since there are other sensitive sectors of the economy the Government is trying to salvage.

The rest of this survey is organised as follows. First, the methodological procedure is described, then the benefits of IoT in education are discussed, followed by the challenges of implementing IoT in Ghanaian tertiary institutions. Finally, we conclude by summarising the significance of the survey.

METHODOLOGY

The survey focuses on the benefits of IoT in education and the implementation challenges in Ghanaian tertiary institutions. As depicted in Figure 2, the first phase of the survey discusses the relevance of IoT in education. Significant application integrations of IoT in smart classroom, smart library, smart data, smart learner, smart administration, smart teacher, smart hostel, and smart healthcare are covered in the study.

The second aspect of the survey discusses the implementation difficulties in Ghanaian tertiary institutions. As depicted in Figure 3, the following challenges of IoT integration were examined: trust, security, and privacy; internet connectivity; network bandwidth; cost of IoT devices; device incompatibility; wireless coverage and battery life; institutional policies and priorities; scalability and reliability; ethical concerns; and dehumanization.

In order to accomplish the objectives of the survey, a search review was conducted across relevant databases, including Scopus, Hindawi, IEEE, MPDI, ScienceDirect, Informing Science Institute, Springer, and Wiley. In addition, a thorough search was carried out using Google Scholar to cover all relevant repositories. The phrases and keywords for the search were made up of five categories. The first category contains keywords associated with IoT and its impacts on diverse sectors. The second category zoomed in on IoT in education. The third search criterion was restricted to the application benefits of IoT in education (smart classrooms, smart libraries, smart data, smart learners, smart administration, smart teachers, smart hostels, and smart healthcare). The fourth aspect of the search includes the difficulties faced with IoT implementation in general and in education. The final category involves integration challenges in Ghanaian tertiary institutions.

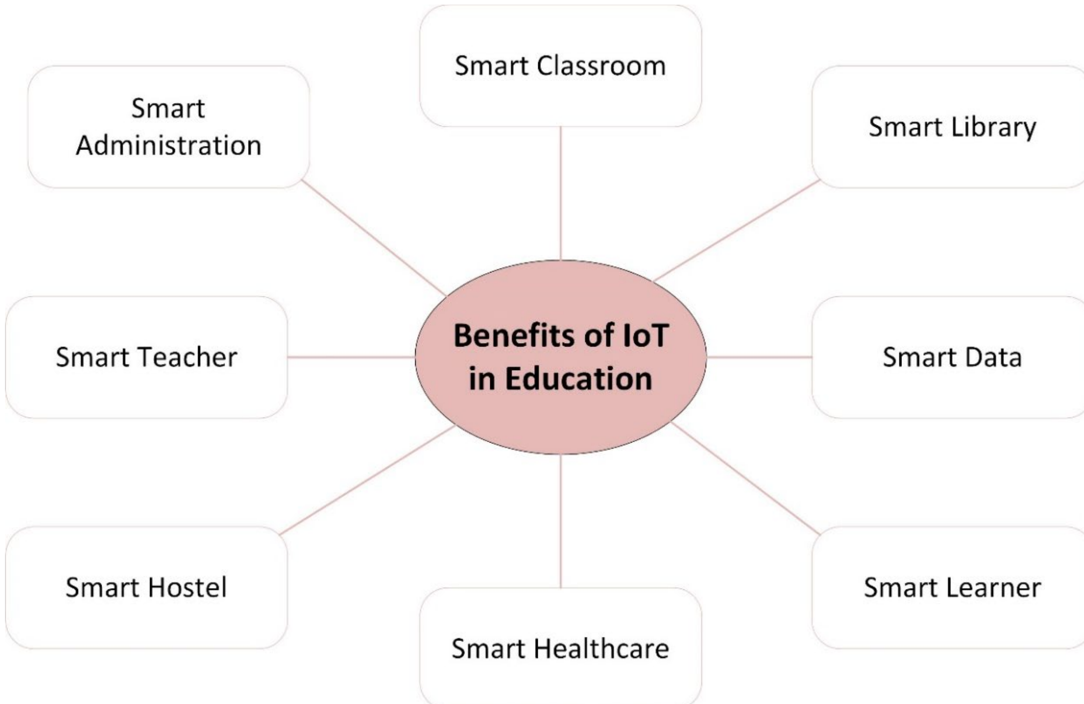

Figure 2. Benefits of IoT in education

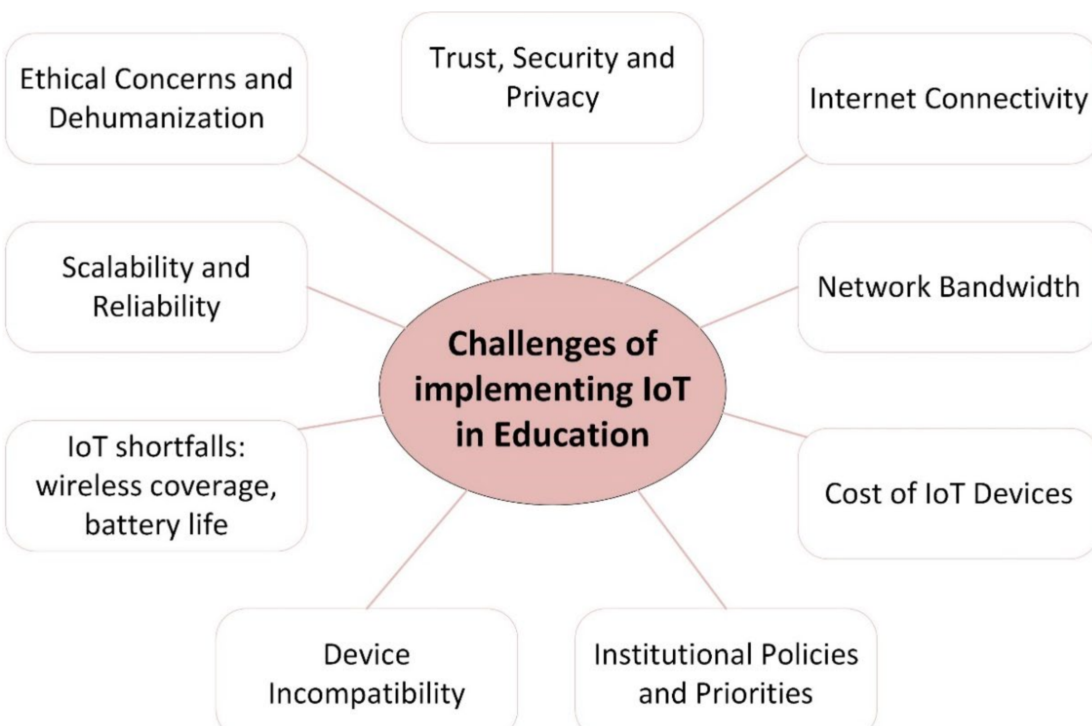

Figure 3. Challenges of IoT in education

An advanced search was performed further using several free-text keywords of Internet of Things and education: "Internet of Things" OR "Smart Campus" OR "Artificial Intelligence" OR "Machine Learning" OR "Smart Teacher" OR "IoT and Big Data" OR "Smart Student" OR "Smart Learner" OR "Smart Classroom" OR "Smart Hostel" OR "Smart Administration" OR "Smart Library" OR "Smart Data" OR "Smart School" OR "Ghana Economy" OR "Ghana and IMF" OR "Ghana and Ghanaian Cedi" OR "IoT in Ghana" OR "IoT in Ghanaian Institution" OR "Challenges of IoT in Ghanaian Institution" OR "Network issues in Ghana" OR "Bandwidth issues in Ghana" OR "IoT and Device Incompatibility" OR "IoT and Scalability" OR "IoT and Reliability" OR "IoT and Ethical Concerns in Ghana" OR "IoT and Cost in Ghana" OR "IoT and Security Challenges" OR "IoT and Battery Life" etc.

The literature search resulted in 300 articles with 200 considered relevant for the survey. Of the 200 articles, 95 shared common themes and discussed the same application integration and challenges. The article selection was based mainly on the application integration of IoT in education and the publication year of the article which generally should not be more than ten years. Other relevant selection criteria include detailed challenges in the implementation of IoT, especially for developing countries, and the articles indexing databases.

BENEFITS OF IOT IN EDUCATION

This survey section discusses relevant applications regarding IoT benefits in education and provides present and futuristic possibilities to improve educational outcomes. The survey includes foreseeable IoT technologies relevant to education. Each module consists of brief definitions with analysis and relevance to diverse applications.

SMART CLASSROOM

As depicted in Figure 4, smart classroom IoT-enabled education encompasses classroom technologies and equipment capable of automating and enhancing engagement with pattern insight during teaching and learning. Saini and Goel (2019) defined a smart classroom as a technology-assisted closed environment that fosters classroom interaction with an intelligent physical engagement between the learner and the teacher. Aguilar et al. (2019) redefine a smart classroom as a confined space that integrates sensor technology, communication technology, and artificial intelligence for a better classroom experience. Any smart classroom must have IoT connectivity capable of developing the next generation of learners (El Mrabet & Ait Moussa, 2017).

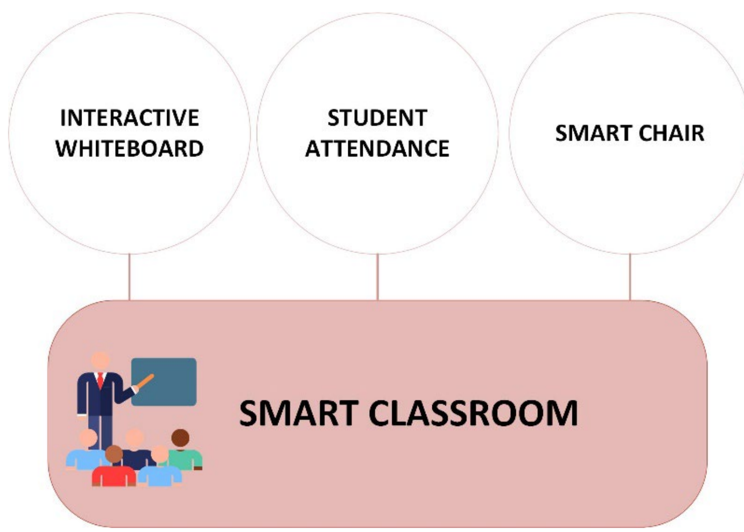

Figure 4. Smart classroom

The IoT-enabled interactive whiteboards project visual elements to enrich the learner's experience. The interactive whiteboards provide various functions through a single device, including tactile effects (Promwongsa et al., 2021), since it is connected to the internet. While students interact with graphics, applications, and videos on the interactive whiteboard using a tool or a finger, teachers gain real-time access to multitudes of educational content with save mode functionalities via fast internet connections. This phenomenon increases learner engagement, curiosity, and active participation while promoting diverse pedagogical philosophies in the learning process (Ormanci et al., 2015). Intel, Amazon, Microsoft, and Google are leading companies that have provided multi-layer IoT-based interactive whiteboards.

Students' attendance and absenteeism have long been a contention for educational institutions (Ezeofor & Georgewill, 2020; Kovelan et al., 2019). In several studies, class attendance has been linked with students' academic performance and has affected learner graduation (Chenneville & Jordan, 2008; Karnik et al., 2020; Nordmann et al., 2019).

An IoT-enabled attendance tracker automates and tracks learners using radio frequency identification (RFID) or fingerprint sensor technology at the perception layer of the IoT-based framework (Al Tarshia et al., 2020; Sittampalam & Ratnarajah, 2019). As an extra perfect attendance measure, modern IoT-based attendance trackers use a camera installed in the classroom to detect images of learners and simultaneously match their faces against a class database (El Mrabet & Ait Moussa, 2020; Turkane et al., 2019). The students' attendance reports are subsequently saved in connected folders with notifications to parents and school administration.

The IoT-enabled smart chair fitted with sensors has tremendous application dynamics in a smart classroom. From reporting learner information to duration in class, the smart chair provides comprehensive data to the instructor about the learners in the classroom (Sodhi et al., 2017). Smart chairs are fitted with RFID readers, pressure sensors, reflection sensors, and indoor localization technologies in the interconnected classroom (Kunhoth et al., 2020; Turgut et al., 2016). The smart chairs have wireless communication capabilities (Enugala & Vuppala, 2018) that connect to camera-based facial recognition detectors to determine learner mood and attentiveness in the smart classroom (Singh & Kaur, 2019). The smart chair collects real-time data, which can be used to make learning more engaging, manage classroom resources, group students, and tailor instruction.

SMART LIBRARY

Libraries play a critical role in the growth of academic institutions and serve as the focal point for the scholarly works of learners (Deo et al., 2020). As depicted in Figure 5, the central functional units of a conventional library span keeping records, book classification, provision of online resources, and tracking book defaulters. The modern-day IoT-enabled library comprises sensing technologies for object connectivity. The data collected from the objects reveals previously undetectable patterns in a conventional library system.

An IoT-enabled physical book recommender system increases the depth of preference of a library user and exposes the student to similar materials (Makwana, 2021). In the connected library, a learner interested in a book is connected to a central database with similar books based on titles and content. Since the bookshelves are linked to the main database, there is a trigger for the learner to find related books with shelf numbers. Soft copy versions of similar books are sent concurrently to the email and phone number of the learner to facilitate downloads and purchases.

The smart library allows user authentication and creates individual profiles for easy borrowing and return. The connected library linked to a central database triggers a notification to users of due dates to return library materials. The issue, renewal, and return of library materials are digitalised, and all these actions are automatically updated in a database. The incorporation of quick response (QR) technology provides a robust authentication system to prevent book theft (Abuarqoub et al., 2017).

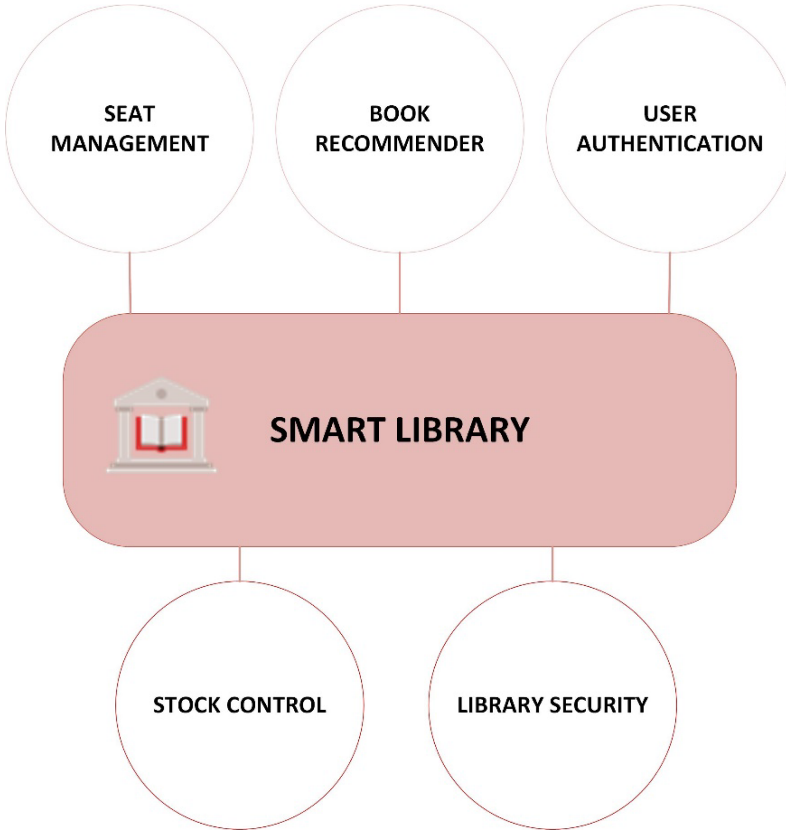

Figure 5. Smart library

Seat management and availability occur in an IoT-based library. Microcontrollers and infrared (IR) sensors are primarily used in a smart library for seat management (Bansal et al., 2018). The work of the IR sensor is to check for seat availability and send information to the microcontroller. The microcontroller processes the information received from the IR sensor and forwards it to the server. The Librarian is mandated to add seats, view student details, and again view seat availability. Users can check seat availability in the library on their smartphones and proceed to book seats.

Stock control possibilities of library contents. Sensors are connected to other library sources, including microfiche, sound, and video. The connectivity enables the monitoring of numerous daily developments in other library materials. The library manager is notified in real-time of the inventory of such materials, resulting in less work for library faculty in stock verification (Bansal et al., 2018).

Security of library premises. Dangerous flames could be managed securely from outside the library by introducing web-associated fire sensors. Sensor-integrated fire detection and prevention gadgets in an IoT-based connected library sound an alert and trigger a message to the fire officers. This automated fire detection secures the library and prevents damage via early detection (Abdel-Basset et al., 2019; Bansal et al., 2018).

Smart Learner

The implementation of IoT in education primarily focuses on developing smart learners, as shown in Figure 6. A student in an IoT-based educational environment has the potential to identify new skills and personalised learning patterns through technology and integrated analytics (Aini, 2020). Digitisation in Education 4.0 completely changes the reactive to proactive learning narrative with informed decisions by the learner. In a connected environment driven by IoT, limitless opportunities exist for the student, from intelligent content downloads to course selection modules (Abdel-Basset et al., 2019).

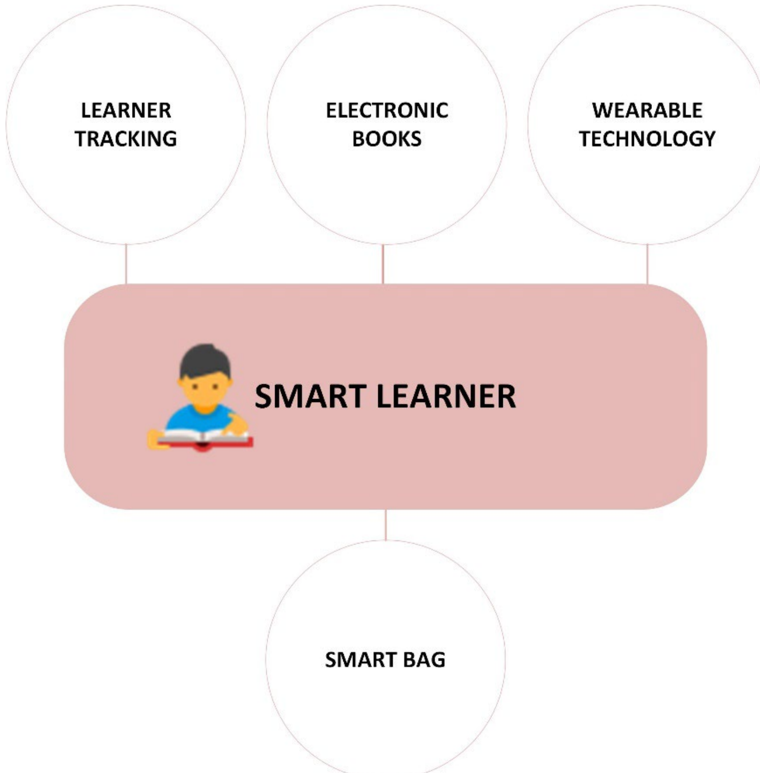

Figure 6. Smart learner

IoT implementation in the learning environment has helped improve students' learning and supported the tracking of students' activities. According to Yakoubovsky and Sarian (2021), integrating IoT tools in online education helps raise learners' performance and efficiency by up to 20 percent. Learners can now individually monitor their progress since IoT sensors can measure one's fatigue level and keep the brain active via continuous engagement.

Learners follow lessons and get interactive with the assistance of smartphone-based online classes, or e-classes. E-books with barcodes arouse learners' interest in reading in an interactive environment. An IoT device, a scanmaker, is used to scan editable text from documents, including books, magazines, and articles, directly into a computing device (Zeeshan & Neittaanmaki, 2021). The scanmaker translates text into 40 languages. Learners, therefore, engage in studying from these interactive-based learning media, which keeps their attention span with diverse educational feedback (Zeeshan et al., 2022).

IoT wearable technology provides seamless learner development. IoT wearable technology integrates students' location information, exercise logs, and social media activities to generate big data for personalised learning (Ciolacu, Binder, & Popp, 2019). A good example is an IoT-ready platform from the MaTHiSiS H2020 EU project (Spyrou et al., 2019). These wearable devices collect data from learners in the form of games by capturing their interaction with learning material using IoT sensing devices. The data collected is then processed, which helps customise the learning environment according to the learner's needs (Spyrou et al., 2019).

The smart bag is an intelligent bag that carries learning materials (Shweta et al., 2016). This responsive bag helps students and parents with innovative services. The smart bag provides the learner with quick timetable management and notifications about missed books and other vital school items (Ajayakumar et al., 2019). The parent of the smart learner simultaneously receives notifications about misplaced school items, which automatically triggers a restock.

Smart Data

In a connected educational environment, the volume, variety, and velocity of data, termed Big Data, has increased tremendously (Daniel, 2019; Reidenberg & Schaub, 2018). This structured and unstructured data is generated from diverse aspects of the educational ecosystem, with complexity usually analysed with machine learning algorithms (Athmaja et al., 2018). The objective of smart data, as shown in Figure 7, varies with monitored pedagogy and analytics, which are crucial to educational growth and reform.

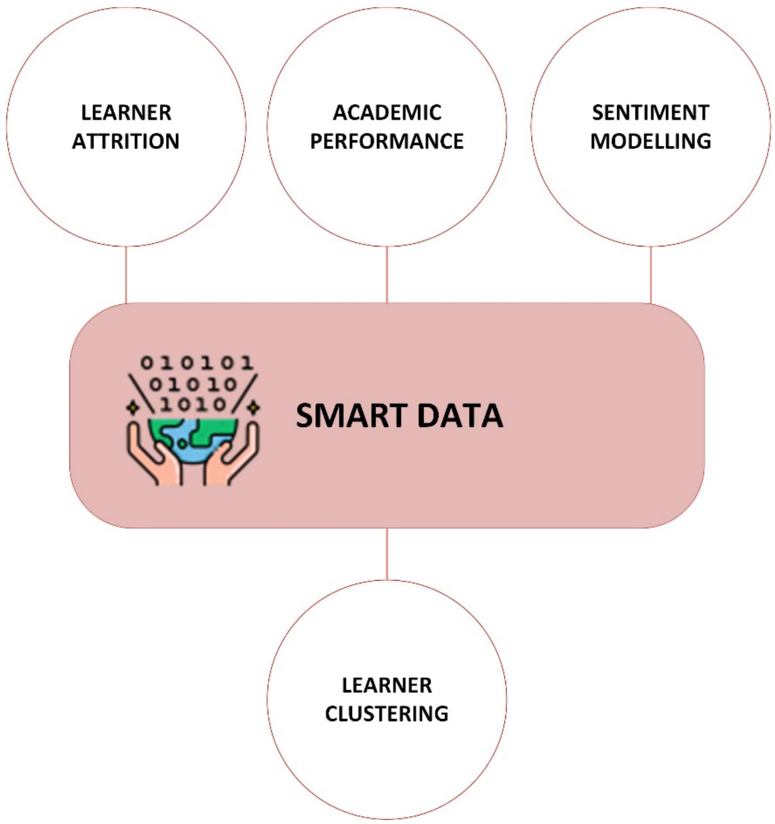

Figure 7. Smart data

The smart data enables academic authorities to identify at-risk students capable of dropping out. Learner drop-out has been problematic for educational institutions even with robust counselling units (Segura et al., 2022). In reducing attrition rates, data analytics with pattern detection trends is a necessity in the prediction and modelling of student behaviours. These proactive, intelligent patterns will inform authorities of dominant factors causing high attrition among learners for personalised counselling (Kemper et al., 2020; Romero & Ventura, 2020).

Students' academic performance prediction is possible because of smart data. Multiple reviews and surveys have discussed the relevance of learner academic performance prediction for early counselling (Alyahyan & Düştegör, 2020; Namoun & Alshanqiti, 2021). Students' academic success, aside from counselling, plays a role in institutions ranking globally. Students' academic performance has other far-reaching consequences, including career success, skills acquisition, academic achievement, learning outcomes attainment, and learner retention (Alyahyan & Düştegör, 2020; Dake et al., 2021).

Sentiment modelling is possible with unstructured data where the tonation behind a text is determined using natural language processing (NLP) (Dake & Gyimah, 2023). Machine learning sentiment detection in an IoT-based environment that generates smart data has become more relevant during the COVID-19 pandemic (Mujahid et al., 2021). The opinion mining of learners has diverse applications, including analysing learner experiences, instructor reflective practices, and institutional recommender systems.

Intelligent learner groupings have a focal point in collaborative learning (Kaendler et al., 2015). In unsupervised learning, smart data generated is essential for learner clustering in educational projects and collaborations (Scheuer & Mclaren, 2012). The clusters generated provide differential guidelines for group projects and skills enhancement (Maina et al., 2017). Even with the increased usage of e-learning systems, learner clustering transcends the traditional classroom into online groupings and monitoring (Peach et al., 2019).

Smart Administration

Smart administration, as depicted in Figure 8, is the application of modern educational technologies that increases the efficiency and effectiveness of day-to-day administrative activities (Zeeshan et al., 2022). In an IoT-based educational environment, connected features allow school administrators to effect changes in a centralised location with Big Data. Smart administration covers all aspects of institutional management, from classroom management, staff management, financial unit procurement, academic calendar, maintenance, recruitment, and security.

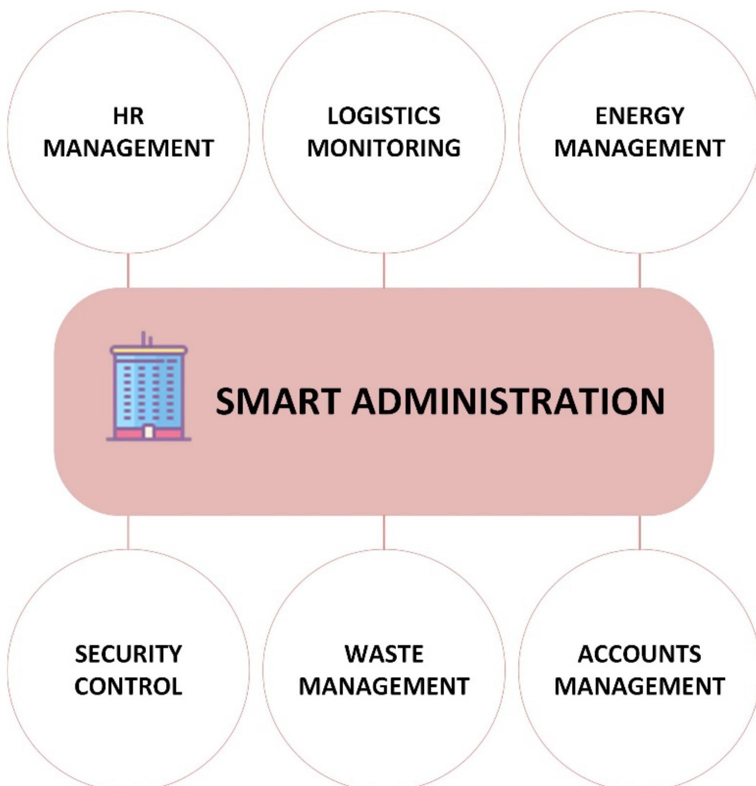

Figure 8. Smart administration

Smart human resource management assigns roles to employees through their smartphones and smartwatches with sensors linked to the human resources division of the school. Teachers are monitored regarding classroom duties and the school environment without managers of such institutions being physically present (Mogas et al., 2022).

Smart logistics dispatch monitoring uses RFID innovation to monitor assets, including laboratory equipment, projectors, vehicles, and other valuables. This intelligent monitoring prevents theft. The module uses RFID tags and hand-held scanners to confirm the stock items in a warehouse, which facilitates automatic stock checking. The global positioning system (GPS) coordinates broadcasts for geographically dispersed assets and monitors asset location to deal with theft issues (Song et al., 2021).

Smart energy management integrates school buildings with IoT for intelligent energy management. This module has a base station with the IoT gateway to provide a communication network, a user interface that interacts and communicates with the system, and appliance controllers that can be controlled remotely (Kim & Lim, 2018). It gathers and analyses the energy data in residential and classroom areas within the school and displays the data in real-time. The system then sends notifications and recommendations to the occupants to help them properly manage their energy consumption and save costs. Smart energy modules in buildings use semantic web technologies (Patel & Jain, 2021) to combine building data with occupants' behaviour, energy prices, and weather information to monitor and learn the energy behaviour of the building. The analytics generated recommend energy-saving solutions to occupants. For occupant demand modification and the building's characteristics, flexibility and scalability are considered.

Smart security uses intelligent devices and sensor nodes for continuous monitoring of the school environment, such as intelligent tagging systems, RFI, GPS-based smart bags, smart watches, and other sensor-based devices (Gul et al., 2017). An authentication mechanism is in place to make these components more secure, and only the owner of the devices can access them and deliver messages from them. Since most tertiary institutions have vehicles, the security extends to smart devices for learners' safety through automatic vehicle entrance records, existing records, and total travelling time in the vehicles. This data is updated and stored in the cloud using high-speed networks (Qiu et al., 2021). Security in the school starts with using RFID cards with auto-tagging and photo authentication, integrated with a tag to ensure more safety, especially when the tag is stolen or misused. In the school environment, sensor nodes are installed at diverse locations to monitor learner activities, location, and presence. Security cameras also help with monitoring. A learner in school wears a smart tag, a band, and a smart bag. These components are connected to parents and school databases using high-speed cellular network capabilities. In case of theft, an immediate surrounding picture is triggered, and an automatic alert message is sent to the school, parents, or nearby security point.

The smart waste management module for the school has garbage bins classified as master and slave dustbins. Master dustbins are equipped with a Raspberry Pi and slaves with an IoT module (Yamanoor & Yamanoor, 2017). Each dustbin with a unique ID has a database of dustbin positions. The dustbin is equipped with ultraviolet (UV) and load sensors for level detection and a humidity sensor for wet and dry garbage detection. Both dustbins communicate with the Raspberry Pi 3 (Pagnutti et al., 2017). The Raspberry Pi 3 gathers the data from sensors attached to master and slave dustbins and sends the data to a server using wi-fi. The message from the Raspberry Pi 3 to the server includes the levels of garbage in a bin, wet and dry waste segregation levels, and dustbin ID. The server matches IDs with the database of dustbins and finds levels of dustbins located in different areas of the school environment. The data gathered from the cloud is analysed using Storm as an analytic tool (Shadroo & Rahmani, 2018). After data collection and analysis, users and garbage vehicles are alerted about real-time garbage levels. The data regarding wet and dry segregation levels will aid in evaluating the current garbage management plans and fine-tuning the strategies for more efficiency.

Smart accounting involves data collection and analysis from the account section linked to management devices via sensors to help management determine the institution's financial status. Fee collection will be done electronically, with no physical cash. Unnecessary employee check-in visits are avoided, reducing costs using remote monitoring and sensors. Accountants are often involved with school risk management (Budding & Wassenaar, 2021). The IoT provides real-time data for accountants to identify, understand, and manage risks. If accountants combine IoT data with financial information, the root cause of financial irregularities is promptly addressed. Priorities are set for improvements by analysing data on asset utilisation, cost, quality, and risk. It is easy to visualise processes within and between other institutions using IoT, CCTV, and augmented reality (López-Belmonte et al., 2023). This improves efficiency and expedites overcoming challenges.

Smart Teacher

As depicted in Figure 9, the smart teacher uses immersive technologies to improve teaching and learning in an IoT-based environment. A shift from standard learning processes to a technologically enhanced environment positively affects the teacher, especially in reflective guides and practices (Karnieli-Miller, 2020). As an expert in the subject area, a teacher facilitates learning and impacts knowledge in learners (Ozen & Yildirim, 2020). A teacher plays a central role in a smart campus architecture, and lapses in teaching philosophies ultimately affect the learner (Xu et al., 2018).

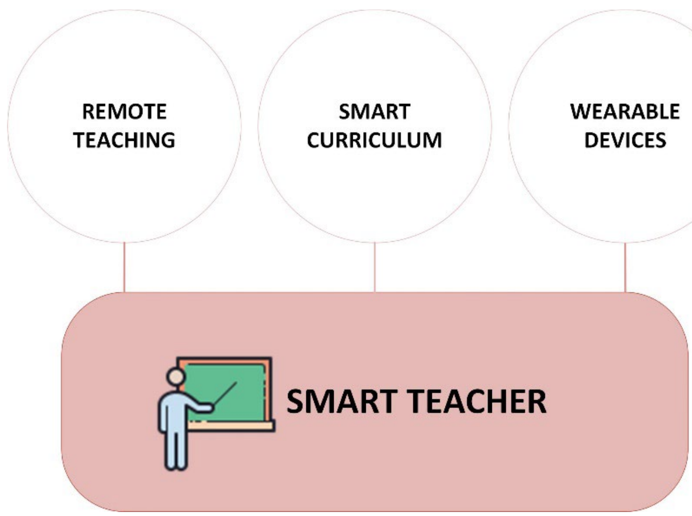

Figure 9. Smart teacher

Remote teaching and assessment administration in an IoT-enabled environment extends learning beyond the classrooms with convenience (Bucea-Manea-Țoniș et al., 2022). Distance and online learning are more efficient with IoT devices that remove time and location constraints and make education accessible for everyone (Moore et al., 2011). IoT-fitted sensors capture data from webcams, microphones, and other distance-learning embedded devices to track learner activities and inform the instructor of learner sentiment, location, attendance, and visuals (Dake et al., 2022). The data collected guides the instructor in content modification, teaching philosophies, class policies, and personalised learning.

The smart curriculum includes course manuals, electronic books, and other resources available across learning platforms that learners can access, devoid of distance and time (Al-Emran et al., 2020). Curriculum primarily refers to lesson content with instructional and assessment policies (Campbell-Phillips, 2020). Automatic suggestions and modifications to the curriculum from learner evaluation feedback inform the smart teacher of best reflective practices and curriculum redesign policies for educational growth. Curriculum assessment and evaluation in an IoT-based environment enables remote tracking of failed instructor policies, with recommendations automatically channelled to appropriate authorities.

In the classroom, IoT-enabled technologies facilitate the teaching and learning process. Interactive smart boards are handy in classrooms to aid the teacher's work instead of the traditional ones (Promwongsa et al., 2021). Wearable devices such as wristbands assist teachers in monitoring the location of learners to track learner patterns and behaviour (Bagheri & Movahed, 2017). Instructors easily check attendance automatically with cameras mounted at vantage points in the classroom and analytic reports sent to parents and management (Alassery, 2019).

SMART HOSTELS

Students' accommodation, as depicted in Figure 10, at tertiary institutions is vital for effective learning (Spio-kwofie et al., 2016; Swanson et al., 2022). Student accommodation challenges negatively impact teaching and learning (Ahmed, 2021; Zakaria et al., 2021). Smart hostels are fitted with sensors and provide diverse application modules to students. The IoT-enabled modern-day hostels are connected to other smart campus architectures to aid the learner (Singhal et al., 2017).

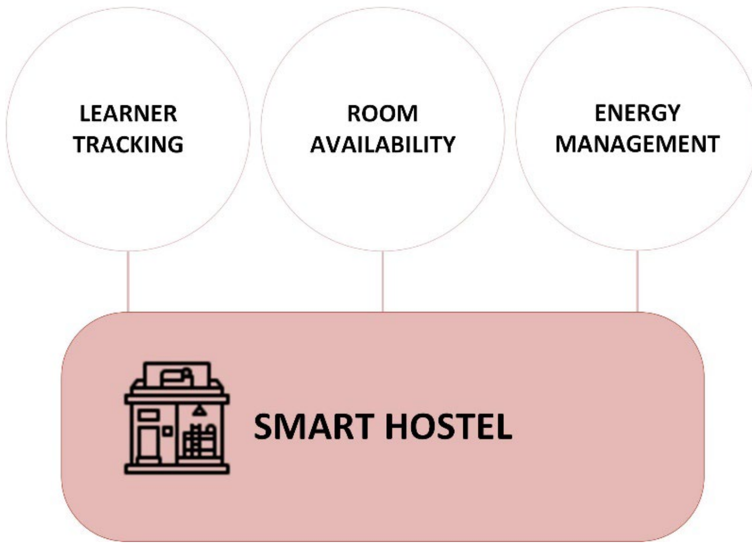

Figure 10. Smart hostel

Students' safety remains a priority to academic authorities and parents. In an IoT-enabled hostel, authorities and parents are notified when respective learners leave and return to the hostel. In an intelligent campus architecture, a time tracker based on the hostel location and means of transportation estimates the students' arrival time on campus (Shouran et al., 2019; Singhal et al., 2017). Automated messages are sent to appropriate authorities and parents when learners don't check in at the IoT-enabled gated entrance within the estimated time.

The availability of rooms, types, and prices connected to students' wearable and mobile devices is one key application area of a smart hostel (Ciolacu, Binder, Svasta, et al., 2019). At the beginning of every academic year, especially in developing countries, room location and pricing remain stressful for students (Shinohara et al., 2020; Simpeh, 2018). In a connected campus, notifications of rooms available across hostels are sent to students with directional maps.

Energy efficiency and management functionality in an IoT-enabled hostel reduce the cost of operation. IoT sensors detect empty rooms and automatically switch unused devices off, which triggers a message to the learner and hostel administrators (Lytvyn et al., 2019). In a smart hostel, greater control of energy utilisation and monitoring saves costs in running the hostel facility.

SMART HEALTHCARE

Students' health is fundamental to learning and key to campus medical facilities and hospitals. According to Tian et al. (2019), innovative healthcare comprises several stakeholders, including doctors, parents, students, authorities, hospitals, and research institutes. It encompasses numerous facets, including disease prevention and monitoring, diagnosis and treatment, hospital administration, health decisions, and medical research (Ahad et al., 2020; Tian et al., 2019).

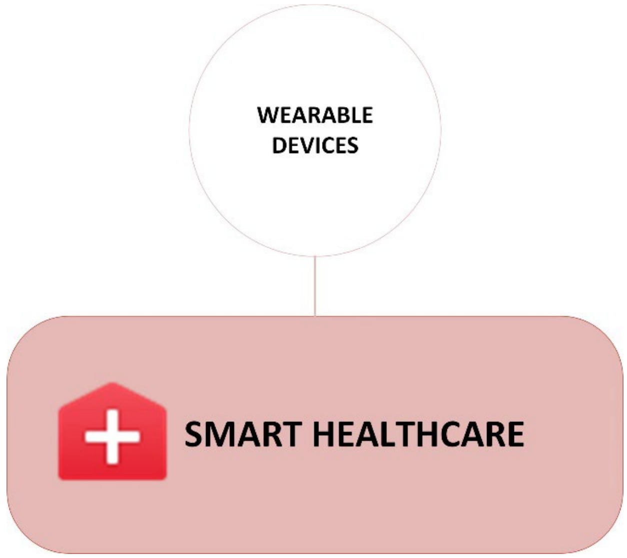

Figure 11. Smart healthcare

Wearable medical devices, as shown in Figure 11, track learners' health and trigger notifications to students, parents, authorities, and medical facilities in an emergency (Hemapriya et al., 2017; Y. Khan et al., 2016). In such emergencies, signals are sent with location trackers of the patients' current location, level of emergency, and type of condition. Automated bed availability or referrals are triggered to ensure speedy healthcare delivery without delays or casualties.

Challenges of IOT Implementation in Ghanaian Tertiary Institutions

The second aspect of the survey considers the challenges of implementing IoT in Education, but some negatives are largely limited to Ghanaian tertiary institutions. As depicted in Figure 3, the challenges to be discussed include trust, security, and privacy; internet connectivity; network bandwidth; cost of IoT devices; device incompatibility; institutional policies and priorities; wireless coverage and battery life; scalability and reliability; ethical concerns and dehumanisation.

Cost of IOT Devices

An IoT-based setup can generally be expensive (Evdokimov et al., 2019; L. Li et al., 2012; Villamil et al., 2020). One cost aspect is the number of IoT devices necessary to cover the implementation modules of an intelligent campus architecture (Barry, 2017). Aside from the cost of purchasing IoT devices, import prices in a developing nation like Ghana are constantly rising due to significant economic constraints (Aduhene & Osei-Assibey, 2021; Yennu, 2018). In addition, Dzawu (2022) recently ranked the Ghana cedis as the worst-performing currency in the world. Ghanaian tertiary institutions are already facing enormous challenges, from infrastructure shortfalls to the devastating COVID-19 outbreak, which has erased the progress made over the years (Arthur & Arthur, 2016; Upoalkpajor & Upoalkpajor, 2020). Even though there are futuristic possibilities to implement an IoT-based connected campus architecture, the current economic outlook makes it infeasible.

Device Incompatibility

According to the Ericsson Mobility Report (Ericsson, 2020), 26.9 billion connected devices will be available by 2026. Additionally, countless IoT-based applications are implemented daily with varying technological support (Pradhan et al., 2021; Siddiqui et al., 2021; Zikria et al., 2021). The lack of consensus over which languages, protocols, and standards are acceptable for various IoT layers leads to device incompatibility. Due to the variability of connected objects, it lacks a single standardisation platform and is constantly changing. Even though these numerous devices from diverse manufacturers operate on the same platforms and perform the same functions, their data formats can vary greatly. Too many firms adopt individual standards, resulting in the development of devices that cannot communicate with each other (Al-Qaseemi et al., 2016). Standardisation makes interoperability possible, improving successful integration and information sharing between remote systems. This indicates a requirement for standard protocols and platforms that can connect numerous devices from various vendors to communicate with one another. IoT standards that are uniform across the board will enhance overall security by making it simpler to secure connected devices for all models (Saimounika & Kishore, 2017).

Scalability and Reliability

Scalability is the capacity of a device to adapt to environmental changes and meet future demands (A. Gupta et al., 2017). Any system that can manage the increasing volume of work must have this crucial component. The elements for scalability are essential and include aspects of commerce, advertising, hardware, software, and networks (A. Gupta et al., 2017; Luntovskyy & Globa, 2019). There is a continuous need for new technologies in education, like high-speed wireless networks, which provide the bandwidth for audio and video streaming of lessons. The devices in IoT are usually deployed in a highly dynamic environment with unreliable connectivity and the extreme possibility of failure in service delivery. Atomic services may exhibit higher dynamicity and lower reliability (L. Li et al., 2012). Even as the 5G network is being trumpeted in other parts of the world, the case of Ghana is different since the 3G and 4G networks are yet to be fully operational (Egho-Promise & Ola, 2020; Gohar & Nencioni, 2021). Since the connected devices need a high-speed network to work efficiently, unstable internet connectivity will affect the reliability of data transfer among devices.

Trust, Security, and Privacy

Typically, devices and systems are designed to be reliable, robust, and secured by cryptographic algorithms and security protocols (El-Haii et al., 2019; Mousavi et al., 2021). Even though IoT provides great opportunities in the educational sector, adding new devices to the network increases the risk of cyberattacks (Stellios et al., 2018). According to Sicari et al. (2015), 57% of IoT devices are vulnerable to cyberattacks. One of the security challenges concerning the implementation of IoT is encryption (Kharroub et al., 2020; Yousefi & Jameii, 2017). Encryption is a common way to keep attackers from accessing data, but attacks have been on the rise with IoT because hackers can easily change the algorithms meant to protect data (Samuel & Sipes, 2019). IoT device manufacturers are more concerned about producing IoT devices without emphasising security. Most of these IoT products are prone to attacks and other security issues since they do not get enough testing and updates (Bures et al., 2019). Emerging IoT devices are vulnerable to brute-force attacks due to weak credentials and default login details (Stiawan et al., 2019; Wang et al., 2017). Educational institutions that rely entirely on the factory default credentials on the IoT devices they acquire put the institution, its assets, and students' and employees' sensitive data at risk of a brute-force attack. IoT usage raises privacy concerns to the point where companies have adopted IoT legal frameworks as policies (Chakray, 2020). The information from users of IoT devices needs protection in an IoT environment, but the autonomous nature of IoT coupled with endpoint communication with other devices primarily exposes user data (Chanal & Kakkasageri, 2020; Gope & Sikdar, 2019; Wigmore, 2014).

Internet Connectivity

The full functionality of IoT devices comes with good internet connectivity (Abdul-Qawy et al., 2015). Internet connectivity is a significant challenge in Ghana, with unreliable service providers and unstable connectivity challenges (Aheto-Domi et al., 2021; Kwapong, 2022). Connecting devices to provide useful fronts and information is enormously valuable, but poor internet connectivity becomes a considerable challenge because IoT sensors are required to monitor process data, and supply information (Mois et al., 2017). According to Samuel and Sipes (2019), 24% of users find connectivity issues the utmost challenge in global IoT deployment. With IoT implementation in education, it is a requirement for various institutions to have a robust communication network to gather data in harsh conditions and transfer it back for analysis at the data centre. However, the signal quality collected by sensors to transmit over to the networks greatly depends on the routers (Samuel & Sipes, 2019). In this regard, a well-connected network via various technologies is needed to facilitate quality and quick communication. These conditions now hinder connectivity since the number of connecting devices is increasing faster than the network coverage (Ericsson, 2020).

Network Bandwidth

Network bandwidth is the maximum amount of data transmitted over a network path in a fixed amount of time (Albishi et al., 2017; Froehlich & Ferguson, 2021; Rikic et al., 2021). While IoT devices are often connected using wired media, most of them operate wirelessly. Though some IoT devices use very little bandwidth, the sheer volume of devices going online asserts that more bandwidth is required. With the rise of IoT implementation, it is prudent to ensure the network can accommodate these changes (I. H. Khan et al., 2020). Even though the network bandwidth of Ghana keeps increasing yearly (Statista, 2022), it is still ranked 135th among countries globally (Speedtest, 2022). The amount of data IoT devices gather and transmit rises as the technology develops, which contributes to the need for increased bandwidth. With IoT demand increasing daily, network capacity is required to be available at the fastest speed possible. With the rise of IoT services and connectivity options, institutions must decide which techniques or methods to employ to ensure they have the required data throughput and range.

Ethical Concerns

Ethics in IoT primarily occurs when vendors are not transparent about client data and usage (Groth, 2022). Information consent is relevant in IoT to alleviate consumer information gathering without permission (Allhoff & Henschke, 2018). Full disclosure and legal documentation between vendors and clients are just as crucial as the devices acquired. IoT devices continue to face information security lapses that unintentionally invalidate consent agreements, leading to mistrust and privacy bridges (Allhoff & Henschke, 2018; Righetti et al., 2018). Ethical concerns also arise when IoT devices meant for a specific function capture other peripheral information without client knowledge and agreement (Allhoff & Henschke, 2018). Vendor negligence coupled with updated functionality without consent agreements raises enormous ethical concerns and privacy concerns in IoT deployments (Atlam & Wills, 2020; Chang et al., 2021).

Internet of Things Shortfalls: Wireless Coverage and Battery Life

IoT devices exist to cover wide ranges based on applications and deployments (S. Li et al., 2018; Whitmore et al., 2015). Linking dispersed devices to process big data adequately requires wireless sensor networks with maximum signal strength (Whitmore et al., 2015). In Ghana, internet connectivity and network bandwidth, as alluded to earlier, remain an issue in successfully deploying IoT in an educational environment. In IoT deployment, battery life is crucial in keeping connected devices online. The low battery life of IoT devices has been studied significantly by Samuelsson (2019) and Chen (2012). In an educational environment where real-time analytics is vital for successful learning outcomes and learner security, IoT sensors going off due to low battery and power fluctuations is a major challenge.

Institutional Policies and Priorities

A shift in institution policies and priorities is vital to the implementation of IoT in Ghanaian tertiary institutions. The Act that establishes tertiary institutions in Ghana defines the mandate, which is integrated into their vision and mission statements (Edu-Buandoh, 2011). Most tertiary institutions in Ghana rely heavily on the limited internally generated fund (IGF) to carry out their primary mandate since government subventions are mostly in arrears (Apaak, 2022; Awotwe et al., 2020). As alluded to earlier, since the Ghanaian economy is already facing enormous challenges, tertiary institutions, instead of investing in long-term innovations and gains, are rather focusing on utilising the IGF for short-term survival and keeping the institutions operational (Awotwe et al., 2020). IoT integration in education will transform teaching and learning positively across all educational levels, but institutional policies and financing must appropriately capture its relevance (Al-Taai et al., 2023).

Conclusion

IoT deployment in educational institutions has significant applications and will speed up the realisation of Education 4.0. With sensors, IoT can collect and transmit big data from varying modules of the educational sector for real-time analytics. With the appropriate machine learning algorithm, hidden patterns can be exposed to guide the learner, instructor, and management. Even as the benefits of IoT deployments are overwhelming in education, the challenges, especially in Ghanaian educational institutions, require urgent attention.

This survey analysed and discussed diverse application deployments of IoT in education. Significantly, we discussed major aspects of educational modules and peculiar application deployments of IoT. The Ghanaian economy currently faces extreme challenges, with IoT deployment non-existent in educational institutions. Even though the benefits of smart campus architecture deployments are apparent, the implementation challenges in Ghana require aggressive policies.

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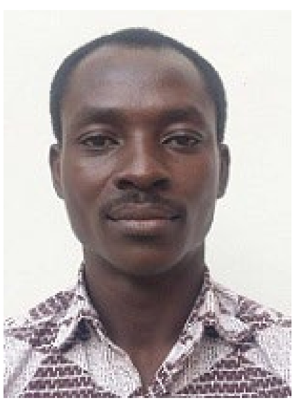

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Discovering Insights in Learning Analytics Through a Mixed-Methods Framework: Application to Computer Programming Education

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Abstract

Aim/Purpose	This article proposes a framework based on a sequential explanatory mixed-methods design in the learning analytics domain to enhance the models used to support the success of the learning process and the learner. The framework consists of three main phases: (1) quantitative data analysis; (2) qualitative data analysis; and (3) integration and discussion of results. Furthermore, we illustrated the application of this framework by examining the relationships between learning process metrics and academic performance in the subject of Computer Programming coupled with content analysis of the responses to a students' perception questionnaire of their learning experiences in this subject.
Background	There is a prevalence of quantitative research designs in learning analytics, which limits the understanding of students' learning processes. This is due to the abundance and ease of collection of quantitative data in virtual environments and learning management systems compared to qualitative data.
Methodology	This study uses a mixed-methods, non-experimental, research design. The quantitative phase of the framework aims to analyze the data to identify behaviors, trends, and relationships between measures using correlation or regression analysis. On the other hand, the qualitative phase of the framework focuses on conducting a content analysis of the qualitative data. This framework was applied to

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historical quantitative and qualitative data from students' use of an automated feedback and evaluation platform for programming exercises in a programming course at the National University of Colombia during 2019 and 2020. The research question of this study is: How can mixed-methods research applied to learning analytics generate a better understanding of the relationships between the variables generated throughout the learning process and the academic performance of students in the subject of Computer Programming?

Contribution
The main contribution of this work is the proposal of a mixed-methods learning analytics framework applicable to computer programming courses, which allows for complementing, corroborating, or refuting quantitatively evidenced results with qualitative data and generating hypotheses about possible causes or explanations for student behavior. In addition, the results provide a better understanding of the learning processes in the Computer Programming course at the National University of Colombia.

Findings
A framework based on sequential explanatory mixed-methods design in the field of learning analytics has been proposed to improve the models used to support the success of the learning process and the learner. The answer to the research question posed corresponds to that the mixed methods effectively complement quantitative and qualitative data. From the analysis of the data of the application of the framework, it appears that the qualitative data, representing the perceptions of the students, generally supported and extended the quantitative data. The consistency between the two phases allowed us to generate hypotheses about the possible causes of student behavior and provide a better understanding of the learning processes in the course.

Recommendations for Practitioners
We suggest implementing the proposed mixed-methods learning analytics framework in various educational contexts and populations. By doing so, practitioners can gather more diverse data and insights, which can lead to a better understanding of learning processes in different settings and with different groups of learners.

Recommendations for Researchers
Researchers can use the proposed approach in their learning analytics projects, usually based exclusively on quantitative data analysis, to complement their results, find explanations for their students' behaviors, and understand learning processes in depth thanks to the information provided by the complementary analysis of qualitative data.

Impact on Society
The prevalence of exclusively quantitative research designs in learning analytics can limit our understanding of students' learning processes. Instead, the mixed-methods approach we propose suggests a more comprehensive approach to learning analytics that includes qualitative data, which can provide deeper insight into students' learning experiences and processes. Ultimately, this can lead to more effective interventions and improvements in teaching and learning practices.

Future Research
Potential lines of research to continue the work on mixed-method learning analytics methodology include the following: first, implementing the framework on a different population sample, such as students from other universities or other knowledge areas; second, using techniques to correct unbalanced data sets in learning analytics studies; third, analyzing student interactions with the automated grading platform and their academic activities in relation with their activity grades; last, using the findings to design interventions that positively impact academic performance and evaluating the impact statistically through

experimental study designs. In the context of introductory programming education, AI/large language models have the potential to revolutionize teaching by enhancing the learning experience, providing personalized support, and enabling more efficient assessment and feedback mechanisms. Future research in this area is to implement the proposed framework on data from an introductory programming course using these models.

Keywords learning analytics, mixed methods, computer programming, correlation analysis, content analysis

INTRODUCTION

The past few decades have seen an increase in the use of technology in education, including computers, electronic boards, virtual environments, and learning management systems. As a result, the amount of data collected during the learning process has increased exponentially, providing potential insights into the factors that contribute to academic success (Baker & Inventado, 2014; Siemens, 2013). This information can guide institutions, faculty, and students in making decisions related to educational administration, teaching, and learning (Kumar et al., 2015; Lazarinis et al., 2022), as well as learning outcomes assessment (Ladias et al., 2022). Learning analytics, which involves the analysis of educational data, is considered the future of education, particularly in higher education contexts (Arnold & Pistilli, 2012; Long & Siemens, 2011). Learning analytics builds on traditional educational research principles, and leverages innovations such as new forms of digital data collection and advanced computational analysis techniques from data science and artificial intelligence (Pistilli et al., 2014).

In the context of computer programming courses, learning analytics has been used for various purposes, such as detecting students at risk of failing a course (Azcona et al., 2019; Lagus et al., 2018), tracking course progress (Shen et al., 2020), and providing personalized feedback to students (Lu et al., 2017). The importance of incorporating learning analytics into computer programming education stems from the inherent complexity of programming tasks (Salguero et al., 2021). For example, students must develop problem-solving skills to tackle complex tasks such as understanding the problem at hand, translating the problem statement into an algorithm using techniques such as pseudocode or flowcharts, manually calculating the output using specific input data, implementing the program based on the designed algorithm, compiling the program, and identifying and correcting any syntax errors or bugs (Aissa et al., 2020). In addition, computer programming courses often face the challenge of maintaining student interest in the field (Margulieux et al., 2020) and ensuring that students acquire the expected knowledge as perceived by their instructors (Salguero et al., 2021). Therefore, having tools and techniques that can help improve the learning design and facilitate student proficiency is of great value (Shen et al., 2020).

However, research by Mangaroska and Giannakos (2017) suggests that quantitative research designs still predominate over mixed methods and qualitative studies in learning analytics. This finding is consistent with those of Macfadyen and Dawson (2010) and Tempelaar et al. (2016), who highlight the limitations of using quantitative data as the sole source of information to understand students' learning processes. This problem arises due to the abundance, greater availability, and ease of collection of quantitative data in virtual environments and learning management systems compared to qualitative data (Mangaroska & Giannakos, 2017).

Thus, in this work, we propose a framework based on a sequential explanatory mixed-methods design in the learning analytics domain to enhance the models used to support the success of the learning process and the learner. The framework consists of three main phases: (1) quantitative data analysis; (2) qualitative data analysis; and (3) integration and discussion of the results. Furthermore, we apply this framework by examining the relationships between learning process metrics and academic performance in the subject of Computer Programming coupled with a questionnaire on students' perceptions of their learning experiences in this subject. We propose to answer the research question:

> How can mixed-methods research applied to learning analytics generate a better understanding of the relationships between the variables generated throughout the learning process and the academic performance of students in the subject of Computer Programming?

The proposed methodological design for this study is non-experimental and uses a mixed approach. The quantitative phase of the research aims to determine the relationships between the calculated metrics of the learning process and the academic performance of students in the subject of Computer Programming. On the other hand, the qualitative phase of the methodology focuses on the content analysis of the qualitative data obtained from a questionnaire in which students expressed their learning experiences in the subject.

This document is structured as follows. The second section provides a description of the conceptual framework and related work on learning analytics, both in general and in the context of computer programming courses. The third section explains the methodological framework of learning analytics based on mixed methods proposed in this research. The fourth and fifth sections describe the preparation, transformation, and analysis of quantitative and qualitative data, respectively. The sixth section presents a discussion of the results, integrating the quantitative and qualitative analysis. Finally, the last section presents the conclusions and future work derived from this research.

BACKGROUND AND RELATED WORKS

LEARNING ANALYTICS

Learning analytics is a multidisciplinary field that studies different aspects of education across different contexts. While it is not the aim to provide an exhaustive review of the extensive literature on the topic, several key aspects can be highlighted. These include academic performance, student retention, motivation (Lonn et al., 2015), engagement (Coffrin et al., 2014), learning gains, satisfaction (Elia et al., 2019), metacognitive skills (Wu & Wu, 2018), and self-regulated learning ability, which is determined by analyzing individual records of academic performance, interactions with course content, and personal information (Kizilcec et al., 2017). Researchers have proposed various models for data analysis and the development of personalized feedback systems (Arnold & Pistilli, 2012), as well as predictive models to identify at-risk students (Monllaó Olivé et al., 2020). Other researchers, such as Andergassen et al. (2014), and Barber and Sharkey (2012), have investigated potential relationships between learning outcomes, student use of the course learning management system (LMS), and demographic information.

LEARNING ANALYTICS IN COMPUTER PROGRAMMING COURSES

The proposed methodological framework of this work aims to apply learning analytics using a mixed research approach in a computer programming course. In the field of computer science, learning analytics has gained significant importance. Specifically, in computer programming courses, researchers are actively exploring ways to predict student behavior and provide personalized feedback. For instance, Azcona et al. (2019) proposed a model to identify students at risk of failing a Python programming course and provide personalized feedback. Shen et al. (2020) used a heat map to visualize student engagement with educational resources and activities in an introductory Python MOOC, examining access patterns and identifying similarities and differences. Lu et al. (2017) applied learning analytics to identify students in need of immediate intervention in a Python MOOC, allowing instructors to create adaptive learning guides based on the information gathered. Macfadyen and Dawson (2010) analyzed the usage tracking data from an LMS used in a course with Blackboard-Vista, while Vahdat et al. (2015) aimed to understand the behavior of systems and computer engineering students in a course using a circuit simulator. Additionally, researchers have also conducted several studies to identify the variables of the learning process that correlate with students' academic performance. For example, Zacharis (2015) developed a model to predict students at risk of low performance using data collected from the Moodle platform.

RELATED WORKS

Researchers have proposed several methodological frameworks for applying learning analytics in educational research. Clow's (2012) cyclical model is a closed loop that compares the investigation's results with a reference point, such as previous data or expected results and design interventions that modify the same learning process studied. Aljohani et al. (2019) proposed a framework that adapts learning analytics applications to the specific requirements of the course, divided into instructional, data, analytical, and presentation levels. Carter et al. (2019) proposed a cyclical process consisting of observable behaviors' operationalization, data collection, data analysis, intervention design, and intervention implementation. Ihantola et al. (2015) established an architecture of the systems and subsystems present in learning analytics research applied in computer science courses. Siemens (2013) proposed a generalizable architecture that uses a top-down approach to systematize the educational resources used.

Despite the progress in learning analytics, there are still several challenges in this field. One of the main challenges is the over-reliance on quantitative methods in research, as opposed to qualitative or mixed methods (Mangaroska & Giannakos, 2017; Tempelaar et al., 2016). Moreover, with the recent shift towards semi-face-to-face or fully virtual classrooms, learning analytics applications based exclusively on quantitative methods face difficulties in comprehending learning processes entirely (Kop et al., 2017; Rienties & Toetenel, 2016). To address this limitation, high-quality educational information is needed to inform decision-making on the generation and implementation of educational interventions (Hilliger et al., 2020).

MIXED METHODOLOGICAL DESIGN FOR LEARNING ANALYTICS

The proposed methodological framework aims to apply learning analytics using a mixed research approach. The research design is non-experimental as the data have been collected without modifying the variables of the context. The proposed design for educational research is complemented by a mixed methods research approach, and an explanatory sequential type of study is suggested for this type of research (Bryman, 2015; Creswell, 2014). The explanatory sequential methodology uses the results found with qualitative methods to find a likely explanation for the findings found by quantitative methods.

Figure 1 illustrates the proposed methodological framework, which consists of three sequential global phases: (1) quantitative data, (2) qualitative data, and (3) discussion. The first two phases are divided into three stages, which are represented in the figure by the dotted black lines. These stages correspond to data preparation, data transformation, and data analysis. The quantitative analysis (Phase 1) is consistent with existing research in learning analytics, which has traditionally focused on quantitative analysis. While the specific approach in Phase 1 may have some novel aspects, it is based on established practices of data collection and analysis in the field of learning analytics. In contrast, the qualitative analysis (Phase 2) and the discussion of the results of both quantitative and qualitative analyses (Phase 3) can be seen as novel contributions of this research. The literature review indicated that the inclusion of qualitative analysis in learning analytics is an emerging area with limited existing research. Therefore, the inclusion of Phases 2 and 3 in the proposed framework adds value by addressing this gap and providing new insights into the learning analytics process. Each of the activities in the proposed methodology is described in detail below.

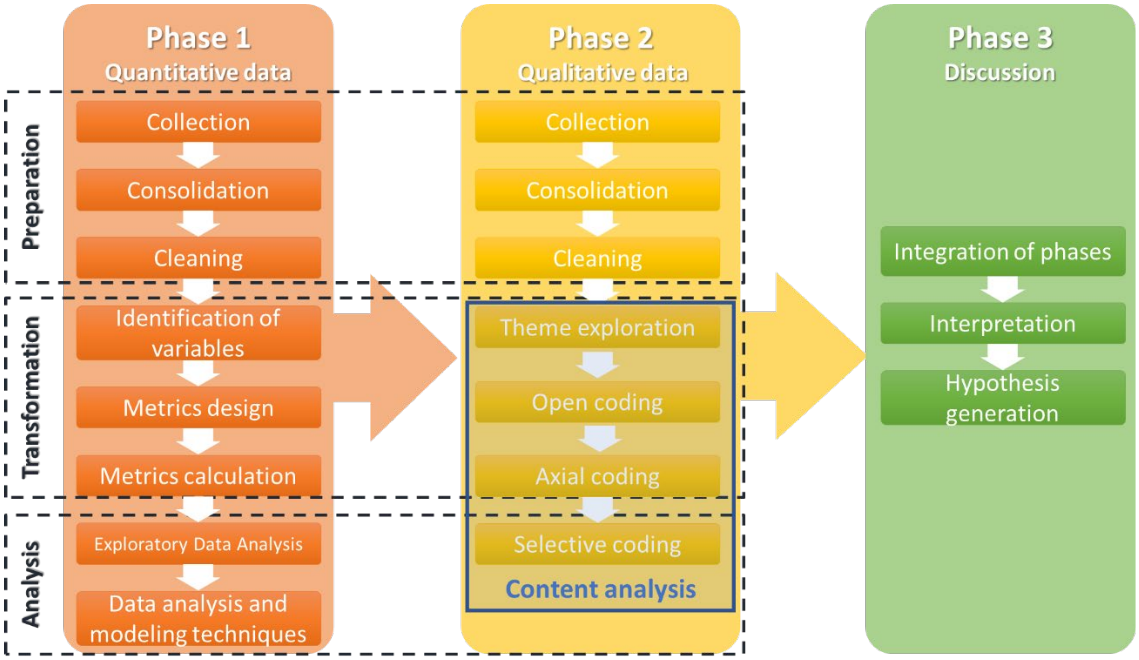

Figure 1. Proposed methodological framework for learning analytics through a mixed-methods research approach

PHASE 1: QUANTITATIVE DATA

In this phase, quantitative data related to students' interactions in the course and their academic performances are collected from the learning platform. This data includes information such as the number of times students accessed the platform, the time spent on each activity, the number of attempts made, and the scores obtained.

This phase begins with the *data collection*, where the location and format of the available data is identified. Then, the data on the students' learning process is gathered using a data management and analysis tool. The next step is *dataset consolidation*, which is necessary because raw data is often disaggregated. During this stage, the most appropriate data structures are identified for the organization and manipulation of the consolidated data.

After consolidation, *dataset cleaning* is performed to identify variables that provide useful information about the learning process. Variables that are not related to the objective of the study or those with data quality issues are discarded. The *identification of variables* follows, where a literature review of measurements and metrics used in educational research in the field of the target course is conducted. The measurements found in the literature that are present in the dataset are then identified, and appropriate metrics are built using them.

Next, *metrics design* is performed, where the equations needed for the estimation of metrics are established based on the results found in the literature. At this point, it is necessary to define the scale (nominal, ordinal, interval, ratio) for the metrics and units of measurement when appropriate. The equations proposed in the metrics design stage are then applied in the data management tool, and the values obtained are stored for later analysis (*metrics calculation*). *Exploratory data analysis* is then performed based on the previous measurements and metrics to identify behaviors and trends. Descriptive statistics, such as the arithmetic mean, dispersion measures, skewness, and visualizations like box plots, histograms, etc., are used during this stage.

Finally, *data analysis and modeling techniques* are applied, and the relationships between metrics and measurements are identified through correlation or regression analysis. In addition, supervised or unsupervised machine learning techniques can be applied if the goal of the work is to obtain classifications, regressions, or clustering of data.

Phase 2: Qualitative Data

To begin this activity, the research design for the qualitative methodology needs to be selected, such as grounded theory, ethnographic study, narrative, phenomenological, or action-participatory research (Hernández-Sampieri et al., 2014). Then, the population sample of interest should be identified, and the research method for the study (*data collection* tools), such as interviews, questionnaires, focus groups, etc., should be selected. All collected data should be stored in a defined location, such as a local storage or a shared file storage platform. The format of the stored files should also be determined, depending on the data source, whether it is text, image, video, or audio files.

The next step is *dataset consolidation*. In this activity, all the collected data is stored in a defined location, and the format of the data set is made uniform. After that, the *dataset cleaning* consists of removing data from the dataset; in the case of records identified as having data that is missing, incomplete, atypical, or irrelevant, it should be removed. In addition, if the amount of data is large, computational tools such as Atlas.ti, Decision Explorer, Etnograph, and NVivo may be used.

The content analysis of qualitative data begins with the *theme exploration*. This activity starts the process of content analysis of qualitative data, which is represented by the blue box in Figure 1. Content analysis is defined by Bryman (2015) as the systematic and reproducible quantification of documents and texts, both printed and visual, in terms of predetermined categories. This is a nonlinear and iterative process, as the tasks of coding and categorizing are not single events within the procedure (Hernández-Sampieri et al., 2014). The basic unit of analysis or meaning is chosen, and the information collected is divided into specific fragments labeled with codes that emerge from the interpretation of the data.

The process of *open coding* involves dividing the data into small fragments and labeling them with appropriate codes that indicate global ideas. Similar codes are grouped and labeled with the same code to ensure that segments related to the same topic are categorized accurately.

The *axial coding* identifies connections between the codes generated in open coding and groups them into categories (Corbin & Strauss, 1990). From these categories, associations are identified, such as causal relationships, context behind observations, or consequences of the phenomenon, and categories can be grouped into general themes.

Finally, *selective coding* identifies the central phenomenon or category that unifies all other categories and themes resulting from previous coding (Corbin & Strauss, 1990). This process, also known as data relativization, may refine some codes and result in the creation, mixing, splitting, or elimination of labels. The step-by-step approach to data relativization is as follows (Corbin & Strauss, 1990):

1. Based on the trends identified in the data, define the central category that groups all the themes and categories of the axial coding and captures the general idea of the qualitative research results.
2. Identify the links between the general category and the rest of the themes and categories to determine the final narrative of the research report.
3. Identify the themes, categories, and codes that appear to be unrelated to the central phenomenon identified and verify whether the amount of data from these labels is sufficient to consider the results relevant. In the case that the information is insufficient, the label should be eliminated.
4. Review the original data again and code the fragments of information considering the general category generated.

Phase 3: Discussion

As the proposed methodological design follows a sequential explanatory mixed methods approach, this phase consolidates the findings of the quantitative phase with those of the qualitative phase. The aim is to explain the findings of the first phase using those of the second phase, which helps to verify whether the behaviors identified through quantitative data are supported or refuted by qualitative data (*integration of phases* stage). This approach broadens the scope of the results of the quantitative phase and generates clarifications of the behaviors found from a qualitative perspective.

The stage of *interpretation* involves a detailed analysis of the research questions and their answers based on the specific results obtained. The results are then compared with the findings of related works that were studied in the literature review. In cases where the results differ from the existing literature, the possible reasons for such discrepancies should be stated, including factors that may be related to the dataset, the course characteristics, and the context, among others.

Finally, the *hypothesis generation* begins with an in-depth analysis of the results obtained, which includes a detailed description of the possible reasons for the identified behaviors. This approach helps to formulate hypotheses that describe aspects of learning processes that may occur in the educational environment under study. Based on these hypotheses, it is essential to reflect on how the research findings contribute to the scientific community, particularly in the field of learning analytics. These findings can guide future research projects and work.

Proposal Application: Quantitative Data

The proposed methodological framework for learning analytics using a mixed-methods research approach is intended to be applied in the context of computer programming courses using educational platforms that facilitate the collection and storage of data on student interactions. The selection of computer programming courses as the context for the case study is primarily intended to demonstrate the practical application of the proposed methodology in a real-world setting. However, it is important to note that the methodology itself can be applied to other domains within the field of learning analytics.

This study analyzes the use of the UNCode platform, an educational platform used in the Computer Programming courses at the National University of Colombia for the automatic evaluation of programming exercises (Restrepo-Calle et al., 2018, 2020). The research question of this proposal application is:

> How can mixed-methods research applied to learning analytics generate a better understanding of the relationships between the variables generated throughout the learning process and the academic performance of students in the subject of Computer Programming?

The study considers two sources of information: (1) the record of students' interactions with the UNCode platform, stored in a MongoDB database, and (2) questionnaires on students' perceptions about the use of the educational platform, stored in spreadsheets by academic period.

UNCode allows students to submit multiple attempts (source code or Jupyter notebooks) to solve programming tasks. For each solution attempt, the platform stores the program file, submission date, and time. It also provides automatic feedback through verdicts related to syntax, semantics, and program efficiency, as well as a numerical grading based on the test cases the program solved. UNCode provides several learners' support tools, such as syntax highlighting, code auto-completion, Linter (suggestions for good programming practices), visualization of code execution, custom tests, and grade reports. Further details on the functionalities of UNCode can be found in Restrepo-Calle et al. (2018).

In the context of the computer programming course, the objective of Phase I is to collect and analyze quantitative data from the students' interactions with the educational platform and their corresponding academic performance, as well as quantitative data from the students' perception questionnaires. The collected quantitative data will provide a rich source of information that can help identify relationships, evaluate performance, plan interventions, and improve the computer programming course for better student outcomes.

DATA PREPARATION

Interaction with UNCode

The study population consisted of students who took the subject of Computer Programming at the National University of Colombia between the first academic period of 2019 and the second period of 2020 (2 years - 4 academic semesters), during which the UNCode educational platform was used in the course activities. The study is limited to 24 computer programming courses that used the UNCode platform to support mandatory academic assignments. The total number of students in these groups was 772. The platform was available throughout the study period. *The data collection* process is performed to select the 16 collections in the database. The selected collections are Aggregations, Analytics, Students Grades, Submissions, Tasks, User Tasks, and Users. The data was then organized into individual folders for each course, which contain the following files:

1. Students: This file contains a list of users identified with the student role.
2. Analytics: Information about the use of UNCode tools by users is stored here. The following five tools are available:
   a. Custom input: This tool enables the design and running of custom tests to evaluate the built programs.
   b. Python tutor: This tool allows visualization of the execution flow of the designed program step by step.
   c. Multiple languages code: This option enables the evaluation of source code written in different programming languages, such as C/C++, Java, and Python.
   d. Linter: A highlighting tool that identifies errors and provides recommendations in the source code based on principles of good programming practices.
   e. User statistics: This file contains statistical reports on the grades obtained by each student.
3. UNCode_grades: This file contains the final grades assigned to each student that corresponds to the weighted average of the grades obtained from the activities performed within the platform.
4. Submissions: This file contains a record of the solution attempts sent by the students in the course activities. Each solution attempt is specified by the date and time of submission, the activity identifier, the username, and the course identifier. Additionally, the file contains the identifier of the file sent, the numerical grade on a scale from 0 to 100, the tests performed, and the verdict obtained.
5. Input: This file contains the specifications of the files sent by each student in each solution attempt. The columns correspond to the file identifier (index), the name of the file loaded on the platform (file_name), and the programming language used (language).
6. Tasks: This file contains information about the course activities developed within the platform. Each file has a column with the course identifier (course_id) and the activity identifier (task_id).
7. User_tasks: This file summarizes the number of attempts made by each student in the course activities.

For *the data consolidation*, each course folder contains a directory containing all the files submitted by the students in each solution attempt. These files are organized into directories per student, which contain subdirectories for each course activity.

Regarding *the data cleaning* stage, first, a filter was applied to select computer programming courses with a high number of activities on the platform. The courses G15-2019-2 and G16-2019-2 have the maximum number of activities, 102. In contrast, G8-2020-1 has the least number of activities, only 15. All courses have sufficient interaction data recorded. However, the pilot courses group-5 and group-6 are discarded, as the platform was used for preliminary study, making their data incomparable to the other courses. Therefore, 22 groups are considered in the final dataset.

Secondly, activities with a low number of submissions are filtered out, using a minimum limit of 15 submissions per activity. Activities with low or no submissions possibly correspond to tests of UNCode operation or optional activities, making the data irrelevant. This filter eliminated 49 activities out of 1404 from the dataset. Activities with notebook-type files are discarded as they are not comparable with source code files submitted in other activities. Three such activities were identified in the course G18_2020_1, reducing the total number of activities in the dataset to 1352.

Subsequently, a student filter is applied based on the total number of submissions registered per student. Some students have few or no submissions registered, indicating early withdrawal. Using the same minimum limit of 15 submissions, 37 students with less than the minimum number of submissions were identified and excluded from the dataset. After this process, the resulting dataset contained data from a total of 735 students.

Perception questionnaires

Moreover, during the same period (from the first semester of 2019 to the second semester of 2020), we conducted a questionnaire-based approach to gather students' perceptions of using UNCode in the Computer Programming courses. The questionnaires were administered to 17 of the 24 course groups, and the responses were stored in spreadsheets by academic period. Although not all course groups participated in the questionnaires due to logistical inconveniences due to instructors' decisions, the representativeness of the selected course groups provides the perceptions of participants from the majority of the groups. Therefore, this fact might not have introduced any potential bias or limitation to the results. The questionnaires were administered before students learned their final grades during week 14 of the course (out of 16 weeks). In addition, the questionnaire was administered via Google Forms, which ensured a convenient and accessible method of data collection. The questionnaires also asked for informed consent from the participants, ensuring ethical considerations in the administration process.

The questionnaire data include demographic information about the students and their responses to questions about their use of the platform. However, only closed-ended questions were considered in this phase, as they provide quantitative data. The questions were presented as statements, and students were asked to answer using a Likert scale from 1 to 6. The statements were as follows:

1. Indicate your level of agreement or disagreement regarding the following statements, with a maximum value of 6 indicating the highest level of agreement and a value of 1 representing the highest level of disagreement:
   a. UNCode was useful in their computer programming learning process.
   b. UNCode was helpful in obtaining automatic grading for the programs you developed in this subject.
   c. The automatic feedback provided by UNCode was useful to know how to correct errors in my programs.
2. Rate the following UNCode features according to how useful you think they are for learning computer programming, with a maximum level of 6 indicating the highest level of usefulness and a value of 1 representing the least level of usefulness:
   a. Testing of programs using user-supplied inputs (custom input).
   b. Programming best practices verification tool (Linter).
   c. Visualization of program execution (Python Tutor).
   d. Performance reports (statistics).

The questionnaire responses on perception are compiled into one file that combines the information from all the courses. Using a Colab notebook, each spreadsheet is converted into a Pandas DataFrame, and then these DataFrames are concatenated into one, which includes the columns with the student's username, date of birth, gender, academic program, and course group (course_id). Furthermore, the responses to the closed-ended perception questions are also included.

To *clean the consolidated data* gathered from the perception questionnaires on the use of UNCode, initially, the dataset is filtered to remove students with insufficient information. This filtering eliminates 33 students, resulting in a final set of 349 students who participated in the perception questionnaire. This number represents 47.5% of the 735 students from the collected dataset with the interaction with UNCode. Next, a filter is applied to the closed-ended questions of the questionnaire, which are answered on a Likert scale. The questionnaire comprises 21 such questions, but 14 are discarded as they have responses from less than 25% of the total number of participants. As a result, only seven of the closed-ended questions are considered in the final dataset, as mentioned above.

DATA TRANSFORMATION

Table 1 lists the 15 measurements that are of interest in this research from the students' interaction with UNCode (*identification of variables*). These are classified into four categories:

1. Submissions: data related to the attempts made by each student to solve programming assignments.
2. Verdicts: data related to the feedback received for each solution attempt.
3. Tool usage: data on the number of times each platform tool is accessed.
4. Academic performance: numerical grading of the submissions made by the students.

Moreover, software metrics of the students' programs are obtained from the source code files submitted as solutions to the programming tasks.

Table 2 presents the 13 measures identified in the dataset obtained from the perception questionnaires (*identification of variables*). These measures are classified into two categories:

1. Demographic data: includes information that characterizes the student sample.
2. Closed-ended questions: include responses on a Likert scale regarding the use of the platform and its tools during the course activities.

Based on the measures identified in Table 1 and Table 2, 25 metrics were developed and categorized as follows (*metrics design*):

1. Verdict rates: These represent the ratio of a specific type of verdict to the total number of verdicts obtained by each student. The equations used to calculate them are specified in Table 3.
2. Tool usage rates: This category refers to the percentage of accesses to a specific tool in relation to the total number of accesses registered for all tools available on the platform per student. The equations used to calculate tool usage rates are also specified in Table 3.
3. Software metrics: This category represents specific characteristics of the source codes created by students. Table 4 describes the metrics and equations used to calculate them, which are based on the number of operands, operators, executable lines of code, and reserved words used in the code built as a solution to the course activities. These software metrics were calculated using the specialized Python libraries. The lizard library is used to quantify lines of code (NLOC) and token count. The radon library is applied to calculate the cyclomatic complexity (G), maintainability index (MI), and Halstead metrics. Subsequently, the average of the metrics of all the files submitted by each student was estimated.
4. Demographic data: Besides the measures related to demographic data from Table 2, this category includes students' age, which is calculated based on their date of birth recorded in the questionnaires and the date of completion.

It is worth noting that the first two categories of verdict rates and tool usage rates are aimed at identifying the most and least used verdicts and tools, respectively.

Table 1. Measurements considered in the dataset from interaction with UNCode

CATEGORY	MEASUREMENT	DESCRIPTION	SCALE	UNITS
Submissions	Total_Submissions	Number of attempts submitted per student.	Ratio	Count
	Duration_of_Submission	Average time spent by students between submission attempts.	Ratio	Minutes
Verdicts	Accepted	Number of solutions with correct answers.	Ratio	Count
	Wrong_Answer	Number of solutions with incorrect answers.	Ratio	Count
	Compilation_Error	Number of submitted attempts that fail to compile.	Ratio	Count
	Runtime_Error	Number of attempts that succeed in compiling but fail during execution.	Ratio	Count
	Time_Limit_Exceeded	Number of attempts that take too long to execute.	Ratio	Count
	Memory_Limit_Exceeded	Number of attempts that exceed the memory available for execution.	Ratio	Count
	Output_Limit_Exceeded	Number of attempts that exceed the expected program output size.	Ratio	Count
Tool usage	Python_Tutot	Number of logged accesses to the Python tutor tool that allows visualization step-by-step execution of a program.	Ratio	Count
	Custom_Input	Number of registered accesses to the Custom input tool where students perform custom tests on their programs.	Ratio	Count
	Linter	Number of registered accesses to the Linter tool, which highlights syntax and style problems in the source code.	Ratio	Count
	User_Statistics	Number of registered accesses to the interactive dashboard to report on students' individual statistics.	Ratio	Count
	Multiple_Languages_Code	Number of accesses to the Multiple Languages tool that allows submission in different programming languages.	Ratio	Count
Academic performance	uncode_grade	Weighted average of grades of the activities performed by students in UNCode.	Ratio	Percentage

Table 2. Measurements considered in the dataset from the perception questionnaires

CATEGORY	MEASUREMENT	DESCRIPTION	SCALE
Demographic data	Birthdate	Day, month, and year of the student's birth.	Date
	Sex	Variable that represents the sex of the student	Nominal
	Academic program	Corresponds to the student's university career, with 15 options available.	Nominal
Closed-ended questions	QUESTION: Learning process	Level of agreement or disagreement in Likert scale of the student with the statement: "UNCode was useful in their computer programming learning process".	Ordinal

CATEGORY	MEASUREMENT	DESCRIPTION	SCALE
	QUESTION: Automatic grading	Level of agreement or disagreement in Likert scale of the student with the statement: "UNCode was helpful in obtaining automatic grading for the programs you developed in this subject.".	Ordinal
	QUESTION: Feedback	Level of agreement or disagreement in Likert scale of the student with the statement: "The automatic feedback provided by UN-Code was useful to know how to correct errors in my programs".	Ordinal
	A_Custom_input	Likert-scale response to the statement: "Rate the following UN-Code features according to how useful you think they are for learning computer programming:", regarding testing of programs using user-supplied inputs (custom input).	Ordinal
	A_Linter	Likert scale response to the statement: "Please rate the following UNCode features according to how useful you think they are for learning computer programming:", regarding the programming best practices verification tool (Linter).	Ordinal
	A_PythonTutor	Likert-scale response to the statement: "Rate the following UN-Code features according to how useful you think they are for learning computer programming:", regarding the visualization of program execution (Python Tutor).	Ordinal
	A_Statistics	Likert scale response to the statement: "Rate the following UN-Code features according to how useful you think they are for learning computer programming:", regarding performance re-ports (statistics).	Ordinal

Table 3. Metrics based on the verdicts and tool usage measures

CATE-GORY	METRIC	EQUATION	SCALE	UNITS
Verdicts rates	Success_rate	$\frac{Accepted}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
	Error_rate_Wrong_Answer	$\frac{Wrong_{Answer}}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
	Error_rate_Compilation_Error	$\frac{Compilation_{Error}}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
	Error_rate_Runtime_Error	$\frac{Runtime_{Error}}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
	Error_rate_Time_Limit_Exceeded	$\frac{Time_{Error}}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
	Error_rate_Memory_Limit_Exceeded	$\frac{Memory_{Error}}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
	Error_rate_Output_Limit_Exceeded	$\frac{Output_{Error}}{\sum_i Veredicts_i} \cdot 100$	Ratio	Percentage
Tool usage rates	Python_Tutor_rate	$\frac{Python_{Tutor}}{\sum_i Tools_i} \cdot 100$	Ratio	Percentage
	Custom_input_rate	$\frac{Custom_{input}}{\sum_i Tools_i} \cdot 100$	Ratio	Percentage
	Linter_rate	$\frac{Linter}{\sum_i Tools_i} \cdot 100$	Ratio	Percentage
	User_Statistics_rate	$\frac{User_{Statistics}}{\sum_i Tools_i} \cdot 100$	Ratio	Percentage
	Multiple_Languages_Code_rate	$\frac{Multiple_{LangCode}}{\sum_i Tools_i} \cdot 100$	Ratio	Percentage

Table 4. Software metrics from source code files submitted by students

CATEGORY	METRIC	DESCRIPTION/EQUATION	SCALE	UNITS
Software metrics	Lines of code (NLOC)	Number of lines of code excluding comments	Ratio	Count
	Tokens_count	Number of tokens of the programming language used in the code.	Ratio	Count
	Cyclomatic complexity (G)	Number of decision blocks contained in the code, plus one. Lower is better.	Ratio	Count
	Program vocabulary (n)	$n = n_1 + n_2$ n_1: The number of distinct operators. n_2: The number of distinct operands	Ratio	Count
	Program length (N)	$N = N_1 + N_2$ N_1: The total number of operators N_2: The total number of operands	Ratio	Count
	Calculated program length (L)	$L = n_1 \cdot log_2(n_1) + n_2 \cdot log_2(n_2)$	Ratio	Decimal
	Volume (V)	$V = N \cdot log_2(n)$ (Acceptable range between 20 and 1000)	Ratio	Decimal
	Difficulty (D)	$D = \frac{n_1}{2} \cdot \frac{N_2}{n_2}$ (Lower is better)	Ratio	Decimal
	Effort (E)	$E = D \cdot V$ (Lower is better)	Ratio	Decimal
	Time required to program (T)	$T = E/18$ (Lower is better)	Ratio	Minutes
	Number of delivered bugs (B)	$B = V/3000$ (Lower is better)	Ratio	Decimal
	Maintainability index (MI)	Measure of how easy to support and change the source code is (0-100). Higher is better.	Ratio	Decimal

DATA ANALYSIS AND RESULTS

This section summarizes the results of *the exploratory data analysis* (univariate analysis) of some of the measures and metrics considered in the dataset. For the total number of submissions made by the students (Figure 2), the average is 176.6 submissions with a standard deviation of 120.8. The standard deviation value corresponds to more than 68% of the average, indicating a high dispersion of the data, which may suggest that students use different techniques in problem-solving. Some students may make many submissions with small changes in each attempt, while others may make extensive modifications resulting in fewer attempts on the platform.

The tool usage (Figure 3) shows that the most used tool is "Custom_input" with 65.0% of the total recorded accesses, indicating that most students prefer to test the effectiveness of their programs with self-designed tests. The usage rates of "Python_Tutor" and "Multiple_Languages_Code" are 17.7% and 12.0%, respectively. The use of "Python_Tutor" indicates that some students find it helpful to observe the step-by-step execution flow of the constructed program, possibly for error location. On the other hand, the use of "Multiple_Languages_Code" reflects the proportion of student interactions related to code submissions in one of the supported programming languages. The least used tools are "Linter" (5.1%) and "User Statistics" (0.5%). The low use of these tools may indicate that students consider the information provided by these tools insufficient to help them improve their constructed solutions.

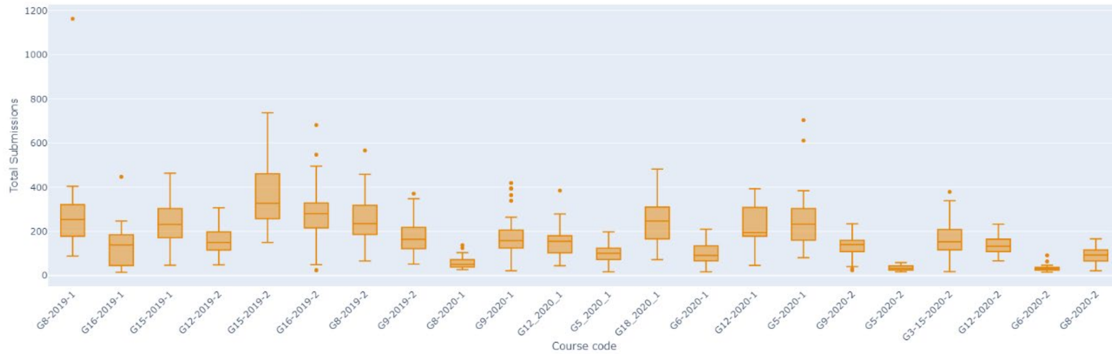

Figure 2. Exploratory Data Analysis: Total submissions box plots by group

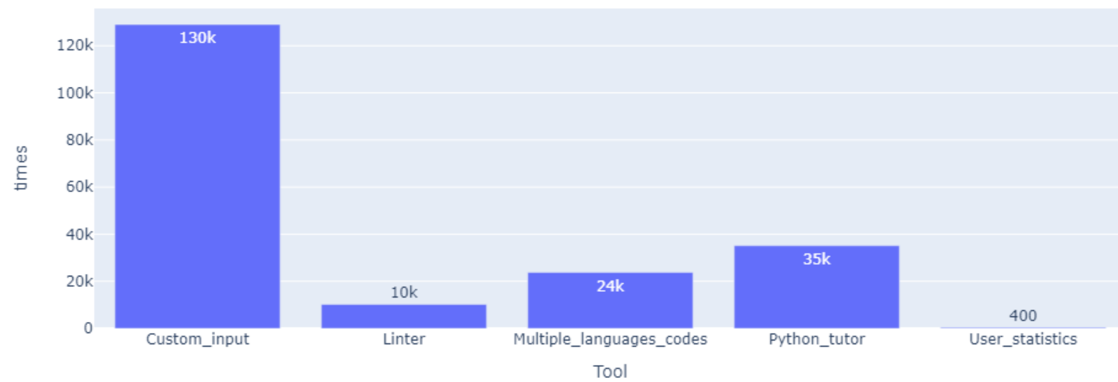

Figure 3. Exploratory Data Analysis: Tools usage

Regarding the verdicts obtained (Figure 4), the judgment with the highest number of records is "wrong answer" (48.9%). This result indicates that most students are successful in designing executable solutions but struggle to meet the specific objectives of the activities. The second verdict with a high number of records is "correct answer" (31.7%), indicating that many students are able to apply the knowledge of the course in solving programming problems. The verdicts that follow in magnitude are "execution error" (14.6%) and "time limit exceeded" (3.9%). The sum of the verdicts obtaining less than 1.0% – "compilation error," "memory limit exceeded," and "result limit exceeded" – represents less than 20% of the recorded judgments, indicating that few students have difficulties or doubts specifically in the executable program design process.

After analyzing the descriptive statistics derived from the software metrics calculated based on the programs constructed by the students, we observed a high degree of dispersion in the data, as indicated by the standard deviations, which are greater than the average in several cases. The metrics with the highest degree of data dispersion are the effort and time required to program, with deviations of 1603.8 and 89.1, respectively. This suggests a wide variety of solutions constructed by the students. On the other hand, the metrics with lower data dispersion are maintainability index (6.4) and difficulty (1.3), corresponding to 10.5% and 35.1% of their respective averages. The low dispersion of these metrics possibly indicates that the students in this course possess similar capabilities and abilities for program construction. These results are consistent with the fact that Computer Programming is an introductory course, and for many students, this is their first exposure to programming languages.

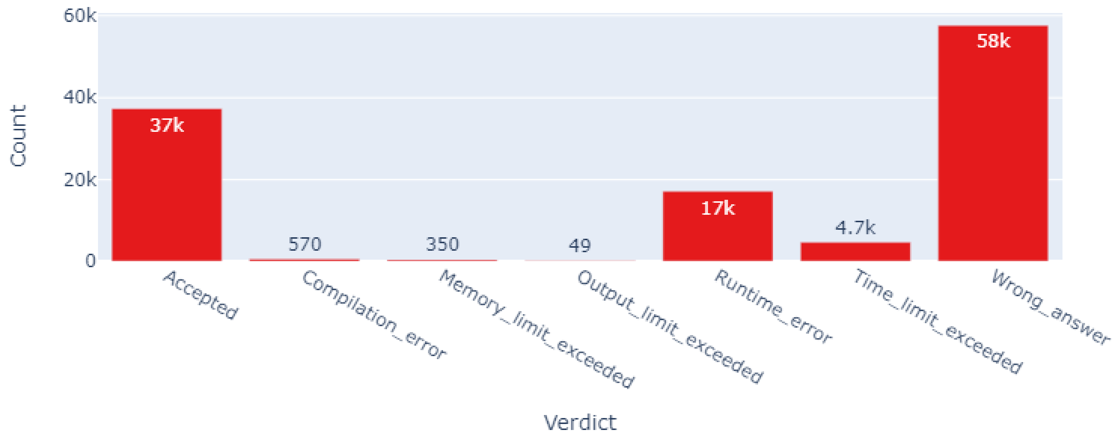

Figure 4. Exploratory Data Analysis: Verdicts obtained in the submissions

Furthermore, a correlation analysis was conducted with UNCode_grade as the dependent variable. Firstly, the Shapiro-Wilks normality test was performed on the academic performance data to determine the appropriate statistical test for calculating the correlations. The test resulted in a p-value > 0.05, indicating that normality cannot be assumed in the data. Therefore, Spearman's correlation coefficient was used as it does not require the samples to be normally distributed. Sex and Academic program variables were not considered in the analysis, as Spearman's coefficient is used to quantify correlations between non-categorical variables. Figure 5 shows the 29 measures and metrics that have a statistically significant correlation (p-value ≤ 0.05) with academic performance.

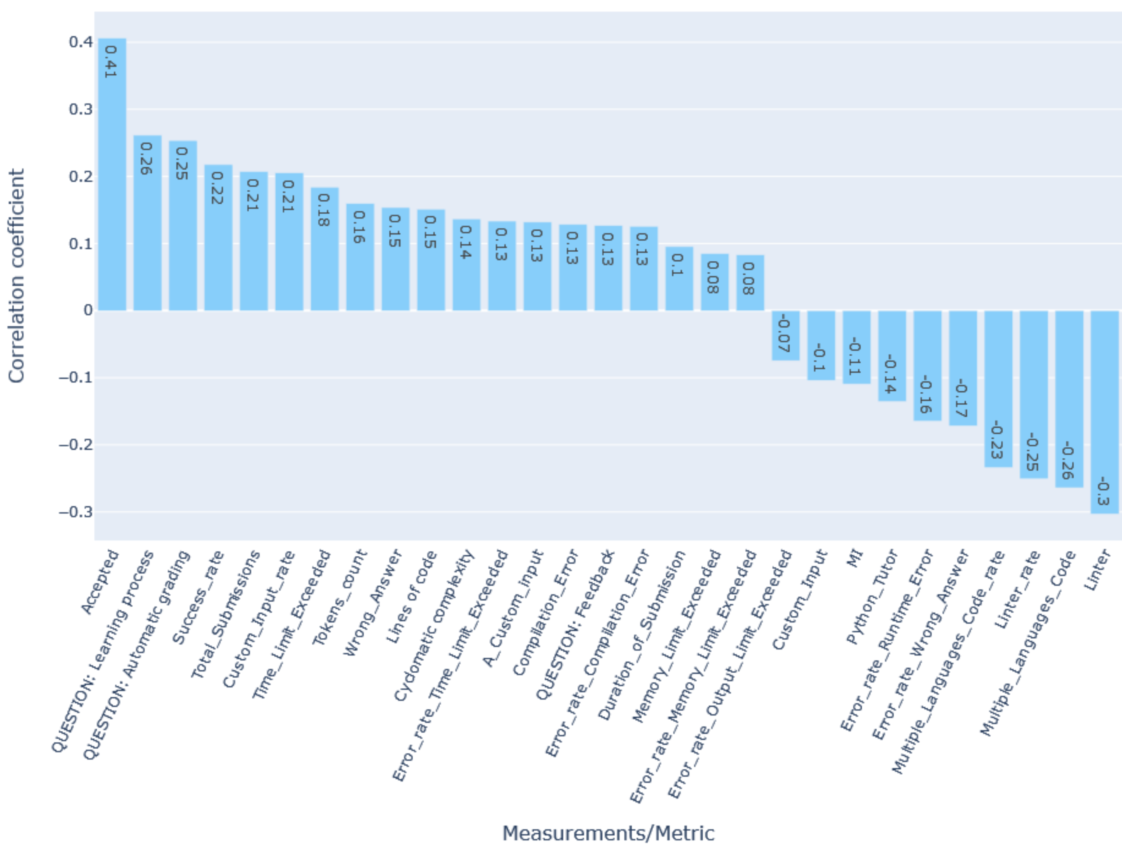

Figure 5. Variables with significant correlations with respect to academic performance

The variable with the highest positive correlation is "Accepted," with a coefficient of 0.41. This is expected, as students who answer more questions correctly are typically more successful at solving course exercises. The next two variables in order of magnitude are "Learning Process" and "Automatic Grading," with coefficients of 0.26 and 0.25, respectively. These results make sense, as students who find the platform useful for learning and appreciate the benefits of automatic grading are more likely to effectively use platform tools and improve their programming skills.

The variable "Success_rate" also has a positive correlation of 0.22, which is expected as students who answer a high percentage of assignments correctly demonstrate strong programming skills. Next, the positive correlations of "Total_Submissions" and "Custom_Input_rate" both with a correlation coefficient of 0.21. In the first case, this may indicate that some students submit many solutions until they get the correct one. In the second case, a student who is able to perform custom tests is likely more knowledgeable about programming and can construct and correct programs more effectively.

In contrast, the variables with the highest negative correlation are the number of accesses to "Linter," "Multiple_Languages_Code," "Linter_rate," and "Multiple_Languages_Code_rate," with values between -0.3 and -0.23. These negative correlations are unexpected, as these tools are designed to support the learning process of students.

The academic performance values were categorized into two groups: passing students (approved), with final grades equal to or higher than 3.0, and students who did not pass the subject (failed). This categorization was done to identify whether the correlations between measures and metrics changed between high-performing and low-performing students. Figure 6 presents the significant correlations ($p\text{-value} \leq 0.05$) for both categories of students.

Focusing on the variables that turned out to be significant in both categories, we observed that six variables had positive correlation coefficients, while one variable had a negative correlation. The positive correlations were found in the variables Accepted, Success_rate, Time_Limit_Exceeded, Total_Submissions, Wrong_Answer, and Error_rate_Time_Limit_Exceeded.

In all cases, the positive correlations were stronger in the group of students who did not pass the course. Moreover, the variable with a negative correlation shared by both groups of students was the Error_rate_Runtime, which was higher in the case of failed students.

At this point in the research, after completion of the Phase I application, it is worth noting that relying solely on quantitative data may leave researchers with unanswered questions and gaps in their understanding of the research problem. For example, what are the underlying reasons for some of the relationships identified? Therefore, in the proposed mixed-methods framework for learning analytics, we emphasize the importance of incorporating qualitative analysis (Phase II) and discussion of the results (Phase III) to address the research questions more comprehensively.

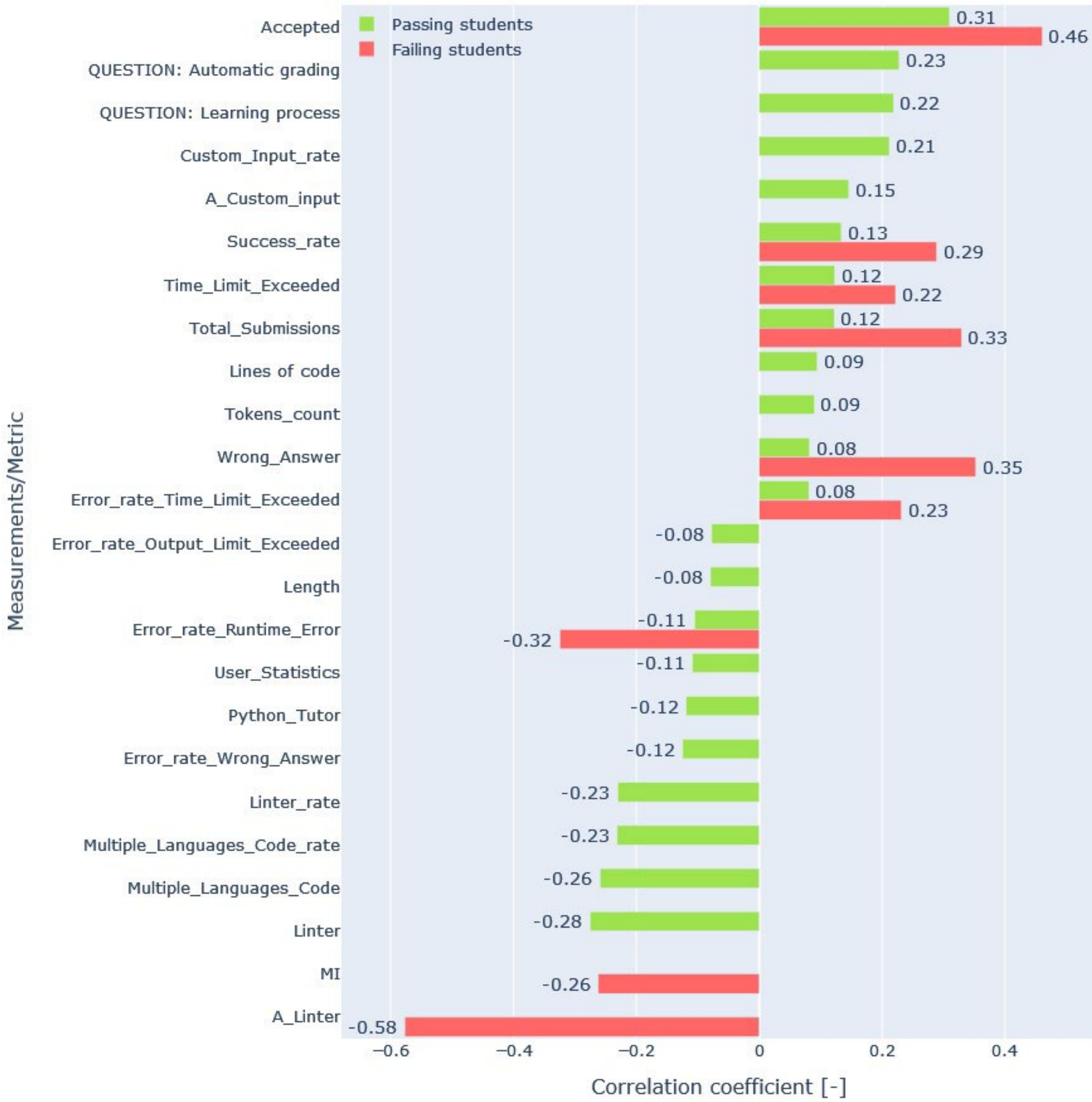

Figure 6. Variables with significant correlations with respect to the academic performance of students discriminated by academic performance (approved and failed)

PROPOSAL APPLICATION: QUALITATIVE DATA

During the qualitative analysis phase, the focus shifts to analyzing qualitative data collected from students' experiences in the computer programming course. Qualitative data may include responses from questionnaires, interviews, or open-ended questions that capture students' perceptions, feedback, and subjective experiences. The methods and analysis of qualitative data seek to find possible explanations for the findings of quantitative methods. The goal is to explain the findings of the first phase with the findings of the second phase, which helps to verify whether the behaviors identified by the quantitative data are confirmed or refuted by the qualitative data. This approach broadens the scope of the results of the quantitative phase and generates clarifications of the behaviors found from a qualitative perspective. By incorporating the qualitative dimension, educators can gain richer insights into students' perspectives, which can inform targeted interventions and improvements in the computer programming course.

Data Preparation

In the quantitative phase, the sample of participants was defined as a subset of the data set from 17 out of 24 Computer Programming courses, covering the period from the second semester of 2019 to the second academic period of 2020 (the *Collection* stage). Perception questionnaires were conducted among students on the use of UNCode in the subject, using Google Forms, and the responses were stored in a spreadsheet for each semester. Only the answers to the open-ended questions of the questionnaire were used in this phase, as they were qualitative in nature. The open questions asked students to explain the reasons behind their agreement or disagreement with the statements of the closed questions considered in the quantitative phase (Table 2). The responses collected from the spreadsheet files were grouped and coded by subject matter to homogenize the data set (*Consolidation and Cleaning* stages). The final data set contains responses from 349 students who participated in the perception questionnaire. The responses were related to open questions on the usefulness of the UNCode platform to enhance learning in computer programming (named ANSWER: Learning process), automatic grading (named ANSWER: Automatic grading), and feedback (named ANSWER: Feedback). The textual answers provided by students in response to each of these three open questions are identified as the basic unit of analysis.

Data Transformation

The stage of *theme exploration* begins the process of content analysis of the qualitative data. This analysis was carried out with the support of the NVivo computational tool. A preliminary review of the basic units of analysis was carried out, identifying recurrent, preconceived, and/or emerging themes.

For the *open coding* stage, the first level of content analysis coding involves assigning one or more codes and categories to each basic unit of analysis. Keep in mind that the open and axial coding process is not a strictly sequential process, and the generation of codes and categories may overlap with the identification of general themes. Additionally, some units may lack detail, and thus only be placed in general themes without category or code. For each of the three questions, the identified categories and codes are listed and described below.

Learning process question

Regarding the learning process question, we generated a total of 5 themes, 21 categories, and 15 codes related to the usefulness of the platform in students' learning process. Table 5 specifies the number of units of analysis grouped by code, category, and general theme, which are classified by students' academic performance. The columns "approved", and "failed" refer to the grouping of responses from the categories previously made during the correlation analysis according to the academic performance of the students. In this way, the column "approved" refers to the number of responses from students who successfully completed the programming course, "failed" represents the number of responses from students who did not meet the requirements of the course, and "total" indicates the total number of responses from students independently of their academic performance. The total sum of references in the table does not correspond to the total number of responses considered, as each basic unit of analysis may be labeled with more than one code, category, or theme. The following categories and codes were assigned:

1. Test cases: References from students highlighting that test cases integrated in the platform help to obtain feedback on the submitted program and identify errors.
2. Formative tips: Mentions of the usefulness of the formative feedback offered by the platform, which provides suggestions about the code construction process in terms of syntax, semantics, efficiency, and maintainability aspects.
3. Knowing the errors: References on how the platform feedback allows students to identify specific errors in the programs built, facilitating the correction and refinement process of the designed solution.

4. Online availability: Benefit for students of the platform working through a web browser, as opposed to programs running in local environments, generating a learning environment where the knowledge acquired can be tested outside the classroom space.
5. Workspace: Platform offers a specific space for the organization of activities, work, and developments made in the course, as a positive aspect.
6. Ease of use: Perceptions about the simplicity of the platform's operation, including the convenience of building and modifying programs directly from the platform.
7. Programming languages: References to UNCode's functionality for selecting various programming languages such as Python, C++, and Java.
8. Constant practice: Mentions of how the platform allows frequent exercise practice, allowing students to strengthen and consolidate the knowledge acquired in class.
9. Custom input: Mentions to the tool that allows performing customized tests by the students.
10. Linter: References to the tool for highlighting syntactic errors and source code style.
11. Python Tutor: Tool integrated into the platform that allows step-by-step visualization of the execution of the programs.
12. Autonomous learning: Mentions of how the platform allows students to expand their knowledge and skills in programming without requiring the direct intervention of the teacher or instructor.
13. Stimulating exercises: Category containing references where UNCode programming problems are characterized as exercises sufficiently demanding to test and strengthen acquired skills and knowledge, without demotivating students due to the level of difficulty.
14. Optimized evaluation: Category assigned to the mentions on how the platform makes the evaluation of the codes submitted by the students much simpler, faster, and more objective. The following four codes are identified in this category: immediate grading, including opinions highlighting the immediacy of the grading, offered by the platform, of the solutions sent in the course activities; objective grading, which mentions the objectivity of the grading obtained in the platform, since the subjectivity of a manual grader is avoided; problem and exercise approach, including mentions on how the platform simplifies the construction of exercises, facilitating the understanding of the context and instructions of the programming problems posed; and submission of academic activities, grouping opinions on how the platform simplifies the process of uploading and submitting solutions to the exercises.
15. Programming skills: Category that contains references on how the use of the platform favors the development of computer programming skills, which transcend from the technical handling of programming tools or languages to relevant long-term skills. Among the skills mentioned by the students, algorithmic thinking, and the understanding of programming logic as a sequential and systematic process stand out.
16. Problem-solving: Category assigned to mentions the development of skills to find the desired solution of computer programming exercises, by means of verification tests together with the comparison of the solution obtained with expected results.
17. UNCode general failures: Category that contains the references about the problematic aspects of the platform that can interfere with the learning process of the students. The following codes are identified within this category (this enumeration is in accordance with the one made in Table 5): (7) Inefficient grading: Reports on errors or inconsistencies between the numerical rating obtained and the quality of the constructed program. (8) Failures in test cases: Reports on the incorrect execution of the test cases of the exercises presented in the platform, which does not allow students to obtain formative feedback in an effective manner. (9) Tools unavailable: Perceptions about how failures in the functioning of the platform tools, hinder the construction and correction of the code. (10) Incompatibility: Mentions of incompatibility of programs developed in UNCode with other code verification platforms. (11) Loss of information: Reports about occasional loss of information within the platform. (12) Platform down: Opinions where the failure of the platform servers is identified as the main inconvenience, preventing student access. (13) Registration: Perceptions about lack of

clarity and inconveniences in the registration process as a user to use the platform. (14) Processing speed: Mentions about significant delays in the processing of the files uploaded by the students to the platform. (15) Visualization: Reports on failures in the visualization interface of both the executed program and the test cases, which do not allow the acquisition of relevant information for the learning process.

18. Inflexibility of the validations: Category assigned mentions the excessive rigorousness of the platform when validating the solutions built by the students. Specifically, it refers to cases where the platform qualifies as incorrect some programs that meet the objective of the exercise but have minor errors of form.
19. Failure in educational objective: Category containing perceptions that state that the platform is not a meaningful tool for the process of learning and acquiring programming skills.
20. Insufficient feedback: Category assigned to mentions the insufficiency in objectivity and detail of the platform feedback. In this sense, some students mention having a perspective of UNCode as a confusing and unreliable tool.
21. Replaceable tool: Category containing references to the possibility of replacing UNCode's functionalities with other available tools or programs, which may even fulfill the platform's objectives more effectively.

Table 5. Number of units of analysis grouped by codes, categories, and themes of the learning process question

THEME	CATEGORY	CODE	UNIT OF ANALYSIS		
			Approved	Failed	Total
Platform Environment			13	1	14
Benefits of the Platform			6	0	6
	Test cases		9	1	10
	Formative tips		21	0	21
		Guides implementable improvements	13	0	13
	Knowing the errors		80	2	82
	Online availability		8	1	9
	Workspace		4	0	4
	Ease of use		32	0	32
		Ease of writing and correcting code	13	0	13
	Programming languages		5	0	5
	Constant practice		17	3	20
UNCode Tools			33	0	33
	Custom input		30	1	31
	Linter		29	0	29
	Python Tutor		69	4	73
Pedagogical Achievements			1	0	1
	Autonomous learning		13	0	13
	Stimulating exercises		39	1	40
	Optimized evaluation		10	0	10
		Immediate grading	22	0	22

THEME	CATEGORY	CODE	UNIT OF ANALYSIS		
			Approved	Failed	Total
		Objective grading	15	0	15
		Problem and exercise approach	15	0	15
		Submission of academic activities	26	5	31
	Programming skills		30	2	32
	Problem solving		66	1	67
Areas of improvement for programming learning	UNCode general failures		45	0	45
		Inefficient grading	4	0	4
		Failures in test cases	5	0	5
		Tools unavailable	6	1	7
		Incompatibility	5	0	5
		Loss of information	3	0	3
		Platform down	14	2	16
		Registration	0	1	1
		Processing speed	5	2	7
		Visualization	5	1	6
	Inflexibility of the validations		13	2	15
	Failure in educational objective		6	5	11
	Insufficient feedback		10	1	11
	Replaceable tool		1	1	2

Automatic grading question

A total of 4 themes, 8 categories, and 7 codes were generated in response to the question regarding the platform's usefulness for automatic grading of student solutions. Table 6 presents the number of units of analysis grouped by code, category, and general topic, and classified by academic performance. The following categories and codes were assigned:

1. Teacher Involvement: Category assigned to units where students recommend that teachers be included in the platform use, specifically in the academic performance evaluation process.
2. Little use of the platform: Category assigned to a few units that report insufficient experience with the platform, as it is possible that few activities have been developed with UNCode in some groups.
3. Autonomous Learning: Category assigned to units that highlight the platform's ability to promote student learning with minimal intervention from the teacher or monitor. The definition of this category is homologous to that established in the question related to the learning process. However, differences are evident with respect to the identified codes, which allows identifying a greater number of components that contribute to autonomous learning. Firstly, a group of references is identified where it is stated that the use of the platform allows students to self-assess their level of knowledge and skills in the subject, which are grouped with the Code of Evaluation Skills. Secondly, there is Formative Feedback, which refers to the provision of quality information to identify errors, improve, and evaluate the quality of programs developed by students. Finally, there is Grade Tracking, where students highlight UNCode tools that allow statistical control of the grades obtained during the semester in the activities carried out.

4. Optimized evaluation: Category where references related to the characteristics and aspects of the platform that allow for effective and appropriate evaluation of the solutions proposed by students are grouped. The codes generated within the category correspond to Immediate grading, Objective grading, and Immediate feedback.
5. Validation failures: Category assigned to comments that report errors in the validation process of developed programs, as they are marked as wrong despite meeting exercise requirements. Some students specify that the grading and evaluation criteria applied by the platform are too strict and inflexible, ignoring small writing errors and semantics, and resulting in poor grades. These references are grouped with the code Inflexibility in checks.
6. General failures: Category assigned to responses where platform failures and problems are highlighted during use. The definition of this category is similar to the UNCode general failure category in the question related to the learning process. However, the errors reported in this question tend to be less specific.
7. Incomprehensible: References that highlight difficulties in clearly understanding the purpose of automatic grading, specifically its functionality or the information it generates.
8. Insufficient Feedback: References that state that the information provided to students when submitting a solution lacks content and explanation, which does not allow for a full understanding of the provided feedback.

Table 6. Number of units of analysis grouped by codes, categories and themes of the automatic grading question

THEME	CATEGORY	CODE	UNIT OF ANALYSIS		
			Approved	Failed	Total
Implementation difficulties			3	0	3
	Teacher involvement		3	0	3
	Little use of the platform		2	0	2
Ease of use			5	0	5
Pedagogical achievements	Autonomous learning	Evaluation of skills	7	0	7
		Formative feedback	63	1	64
		Grade Tracking	7	0	7
	Optimized evaluation		19	0	19
		Immediate grading	73	2	75
		Objective grading	71	6	77
		Immediate feedback	22	1	23
Areas of improvement for automatic grading	Validation failures		20	0	20
		Inflexibility in checks	20	3	23
	General failures		12	0	12
	Incomprehensible		3	0	3
	Insufficient feedback		2	1	3

Feedback question

Regarding the question on the platform's usefulness for providing automatic feedback on student solutions, a total of 4 themes, 5 categories, and 3 codes were identified. Table 7 shows the number of units of analysis grouped by code, category, and general theme, and classified by academic performance. The categories and codes assigned were:

1. Hidden test cases: Units that highlight instances where the difference between the obtained and expected results is not visible, making it difficult for students to identify errors.
2. Insufficient guidance: Units where it is highlighted that the feedback obtained is not sufficient, since in some cases the information acquired does not allow to specifically identify errors or the way to correct the program. Some causes of this include minor errors that go unnoticed by the platform and lack of clarity in explanations and instructions. The consequence implies an autonomous obligation in the process of correcting the developed programs by the students.
3. Comparison with expected outputs: Units that reference the usefulness of comparing the output generated by the student's program with the expected output to identify errors and correction strategies.
4. Correcting errors: Units where students affirm that clear identification of errors in their code is crucial to understanding the type of mistake made and the most appropriate correction strategies.
5. Specific feedback: Units where feedback generated by the platform is described as highly detailed and specific, aiding in timely problem-solving in programming.

Table 7. Number of units of analysis grouped by codes, categories, and themes of the feedback question

THEME	CATEGORY	CODE	UNIT OF ANALYSIS		
			Approved	Failed	Total
Clear initial conditions			6	2	8
Areas of improvement in feedback			2	0	1
	Hidden test cases		12	0	12
	Insufficient guidance		35	0	35
		Minor details	7	2	9
		Lack of clarity	47	3	50
		Autonomous error identification	12	0	12
Problem solving			157	0	157
	Comparison with expected outputs		33	2	35
	Correcting errors		51	3	54
	Specific feedback		60	2	62
Pointing out errors			89	3	92

During the *axial coding* stage, categories were grouped into general themes for each of the three questions, as can be seen from Tables 5 to 7 (first column). For the learning process question, five general themes were generated including platform environment, benefits of the platform, UNCode tools, pedagogical achievements, and areas for improvement. For the automatic grading question, four general themes were generated including implementation difficulties, ease of use, pedagogical achievements, and areas for improvement. For the feedback question, four general themes were generated including clear initial conditions, areas for improvement in feedback, problem-solving, and pointing out errors. The categories with the highest number of records were identified for each general theme, indicating areas where students had the most positive or negative perceptions of the platform. Overall, the findings suggest that the platform is useful for learning computer programming, but there are areas for improvement in terms of teacher support, clarity of feedback, and the operation of the platform.

DATA ANALYSIS AND RESULTS

Based on the results of the open and axial coding, the *selective coding* stage was carried out. First, it is found that the UNCode toolset, especially Python tutor, Custom input, and Linter, is the practical basis of the benefits of the platform. In other words, the strengths, and possibilities of UNCode that contribute to the learning of computer programming are represented through the platform's own options. These benefits allow students to obtain pedagogical achievements that students believe are achieved due to the use of UNCode. These pedagogical achievements can be divided into three groups: development of programming skills, autonomous learning, and optimized evaluation.

There is a reciprocal association between the first two achievements. By promoting the development of important programming skills, students acquire capabilities, knowledge, and confidence, which fosters learning processes with little or no intervention from teachers and assistants. UNCode provides students with the means to enhance their programming abilities. The platform's Python tutor tool, for instance, offers a practical environment for practical coding by means of interactive visualizations. This hands-on experience helps students improve their understanding of programming principles and techniques. Additionally, autonomy in learning allows students to consolidate knowledge such as logical thinking and program construction. By allowing students to independently explore programming concepts and experiment with coding, the platform enables them to develop their problem-solving skills and gain a deeper understanding of how to construct effective programs. The third academic achievement relates to the optimization of the evaluation of the programs submitted by students and is represented in two aspects: (1) the simplification of the process of submission of course activities, and (2) the objectivity and speed in the grading of the solution submitted by the student. The objective and immediate grading has become a distinctive feature of UNCode, providing reliability and efficiency to the operation of the platform.

However, there are also aspects that could be improved, which can significantly affect and hinder the student's experience, deteriorating the overall perception and assessment of UNCode. General malfunctions, such as platform crashes when there is a high volume of users connected concurrently, can directly hinder participation in academic activities, affecting the optimization of evaluation, identified as the platform's benefit. Another aspect to improve is the perceived inadequacy of the guidance offered by UNCode. The lack of information or clarity in the feedback can hinder or slow down the processes of autonomous learning. In some cases, insufficient instruction may compromise students' ability to solve programming problems as they do not obtain sufficient information to identify strategies to solve errors. The third aspect to improve is the inflexibility in the validation process. If the platform rates programs as erroneous despite meeting exercise requirements but having minor errors, it can create a sense of failure among students. This perception of harsh grading may discourage learners and undermine their confidence, even when they have made significant progress in their programming skills. Improving these aspects can enhance the student experience and address potential barriers to effective learning. Ensuring platform stability, providing clear and informative feedback, and adopting a more flexible validation process that recognizes and acknowledges students' efforts would contribute to a more positive and supportive learning environment within UNCode.

Finally, a systematic comparison was made between the responses of those who approved (passed) the course and those who did not (failed). This was aimed at evaluating the hypothesis about the effect of passing or failing the course on the perception of the use of UNCode. However, no differences attributable to belonging to either group were found in any of the themes, categories, or codes. At first, it could be stated that the difference between groups is not evident, due to the imbalance in the number of members of each group, but it can be observed that at the discursive level, there are no substantial differences either. Therefore, it can be concluded that the perception and valuation of the platform appear to be independent of the course outcome, suggesting that factors other than course performance influence how students perceive and evaluate UNCode.

PROPOSAL APPLICATION: DISCUSSION

INTEGRATION OF PHASES

The *integration of phases* stage consisted of analyzing together significant correlations results presented in the quantitative data analysis phase with content analysis results described in the qualitative data analysis phase. The measures and metrics can be divided into five categories according to the type of data they represent: obtained verdicts, solution attempts, tool usage, closed questions in the perception questionnaire, and software metrics.

The study found that the feedback generated by verdicts has a positive effect on students' learning process. Students obtained relevant information through verdicts that helped them know errors and develop programming problem-solving skills and promote autonomous learning. They perceived the UNCode platform as an objective and efficient tool for validating constructed programs. Positive correlations between verdicts and academic performance can also be linked to other platforms' benefits, such as formative tips, constant practice, and ease of use. Regarding automatic grading, error verdicts correlated with academic performance may be linked to some platform's pedagogical achievements such as objective grading, immediate grading, and formative and immediate feedback.

Areas of improvement identified in the qualitative phase include minor syntax details, lack of clarity and insufficient guidance, malfunctioning, inflexibility, insufficient feedback, incomprehensible, and validation failure. These categories are similar across different questions and are related to incorrect responses due to minor formatting errors, incomplete or not useful verdicts, and visualization and test case execution issues. Moreover, it is important to consider that these areas for improvement identified through the qualitative analysis can inform the development of new metrics to be considered in the quantitative analysis of future studies that capture aspects that may influence or hinder the user experience in a timely manner.

We also analyzed the relation between the number of solution attempts made by students and various factors of the UNCode platform. The results showed a positive correlation between the total number of attempts made and the academic performance of students. This might be related to the platform's benefits identified by students such as the possibility to practice constantly, online availability, stimulating exercises, workspace, and ease of use. Students who perceived UNCode as an easy-to-use tool tended to use the platform actively by sending a high number of solutions. The platform's constant availability also generated an exclusive workspace for the student, which allowed for constant practice of exercises even outside of class, resulting in a high number of registered attempts. However, the study also identified aspects that some students considered should be improved within the platform, which negatively affected the number of solutions sent. For example, general failures, inflexibility of the validations, and insufficient feedback were identified as obstacles to sending solutions. Incompatibility with programs developed in other external development environments meant that students opted for external tools for program development, evaluation, and correction, and used UNCode only to submit the final program, which limited the number of attempts registered in UNCode.

Regarding the tool usage and the correlation between it and students' academic performance, seven measures show a significant correlation with student performance, with custom input rate having a positive correlation while the rest have a negative correlation. The rate of custom input usage might be related to the references of custom input in the questionnaire; this indicates that students who perceive the option to evaluate programs built with custom tests as a useful tool tend to prefer to use this tool, as they have the skills to design tests to debug the proposed solution and obtain good academic performance. However, the negative correlation found for the other tools and academic performance is opposed to results found in the qualitative analysis, where we found positive students' perceptions with respect to UNCode tools, especially those related to Python tutor and Linter.

The quantitative phase of the study also shows that some students' responses to the closed-ended perception questions in the questionnaire have a significant positive correlation with their academic performance. Specifically, the questions related to the usefulness of UNCode in the learning process, automatic grading, and feedback all had positive correlations. The qualitative phase supports these findings, as most students identified the positive aspects of the platform in their open-ended responses. In particular, more than half of the surveyed students recognized the benefits of using UNCode in programming learning, pedagogical achievements, and promoting problem-solving. The use of custom input, identified as a tool in the learning process question, also had a significant positive correlation with academic performance.

In the final analysis of the software metrics, the quantitative phase showed that three metrics – token count, lines of code, and cyclomatic complexity – had a positive correlation with academic performance, while the maintainability index (MI) had a negative correlation. It is possible that this positive correlation is due to students who developed longer programs in terms of tokens, lines of code, and the number of possible paths within the program execution. However, the findings from the qualitative analysis did not provide such technical details in relation to software metrics, making it difficult to integrate them with the quantitative results.

Interpretation

The research question of this proposal application on how mixed research methods applied in learning analytics can enhance the understanding of the relationships between variables generated throughout the learning process and the academic performance of students in computer programming can be answered through the integrated results summarized below.

Our findings suggest that students' academic performance is positively correlated with the number of accepted programs (correct responses), success rate, the amount of exceeded memory limit errors, compilation errors, verdicts, and exceeded time limit rates. Considering the perceptions about the platform as a source of formative feedback, it is possible to conclude that these verdicts not only permitted students to identify errors but also provided guidance for correcting the constructed program, which generated problem-solving skills and autonomous learning. This indicates that students possibly acquire sufficient knowledge to successfully solve course activities, which is reflected positively in academic performance. These results support previous research findings that the accumulated percentage of correct exercises has a significant correlation coefficient of 0.67 with student academic performance (Azcona et al., 2019). Additionally, our study found that the positive correlation of the number of incorrect responses (Wrong_Answer) might be related to test case references and comparison with expected outputs, indicating that the use of standardized tests for automatic program evaluation is effective as formative feedback, benefiting student academic performance.

Regarding the use of UNCode's tools, despite the negative results found in the correlation analysis regarding academic performance, these negative correlations are refuted by references in the questionnaire responses that identify Python tutor, custom input, and linter as contributing elements within the platform and as benefits of the platform. These results are also in line with previous findings of studies conducted by Restrepo-Calle et al. (2020) and Ramírez-Echeverry et al. (2022), where students' perceptions of UNCode's use as a learning support platform were also analyzed. Within these investigations, it is evident that students recognize the visualization tool of code execution (Python tutor) as an added value of the platform, which is associated with the identification and correction of errors. Additionally, students highlight the tools for verification of good programming practices (Linter) and tests with customized inputs (Custom input). Moreover, the use of user statistics has a non-significant correlation, which is consistent with research conducted by Zacharis (2015), and Macfadyen and Dawson (2010), where the number of accesses to the grading tool does not show a significant correlation with the grade. This result can be related to a small percentage of responses that indicate monitoring grades as part of their pedagogical achievements, suggesting that the majority of students is not aware of monitoring their academic achievements and therefore has no noticeable impact on the learning process.

Furthermore, the total number of attempts made by students has a positive correlation with their final grade, which can be attributed to positive aspects perceived by students, such as stimulating exercises, ease of use, constant practice, online availability, workspace, and platform environment. The relationship between these results suggests that high-performing students may use the platform as a source of feedback to improve their solutions by making multiple attempts at the same activity. The platform provides a workspace that facilitates the presentation of academic activities, is user-friendly, allows for the creation of stimulating exercises, and encourages constant practice since it is available even outside the classroom. This result is consistent with Zacharis' (2015) research, which found a positive correlation (0.2 to 0.39) between the number of activities submitted during the course and the final grade.

Moreover, the positive correlation of time between attempts can be associated with the group of students who highlight the immediate feedback and the writing and correction aspect as positive characteristics of UNCode. These results are consistent with the findings of Andergassen et al. (2014), who obtained a positive correlation of 0.18 between the average time difference between repetitions (i.e., attempts) of exercises and the final exam grade. These results indicate that due to the speed of the evaluation process on the platform, students with good academic performance possibly invest most of their time in building and correcting the solution between each submission. Another of the results obtained is the positive correlations of perceptions in the three closed questions (QUESTION: Learning process, QUESTION: Automatic grading, and QUESTION: Feedback), which are corroborated by the answers to the open questions, where most students identify pedagogical achievements and the benefits of the platform. This probably indicates that users who have a positive experience with the platform tend to identify and take advantage of its benefits, achieving good academic performance.

Our findings of a positive correlation between academic performance and the cyclomatic complexity metric contradict the results of Vahdat et al. (2015), which found a negative correlation between the two variables. Furthermore, previous works in this context have shown no significant correlation between these variables (Castellanos et al., 2017). Therefore, it is necessary to further explore these relationships to improve our understanding of this situation.

The results of this research provide insights into how automatic formative feedback can be beneficial to the learning process for students. Nevertheless, some students highlight that this type of feedback needs to be complemented with instructor guidance to achieve their objectives. Furthermore, allowing students to design personalized tests appears to be a useful approach for constructing correct solutions. The study also found that high-scoring students tend to make the most attempts and use the majority of their time correcting their programs. Additionally, it emphasizes the importance of ensuring that students understand the platform's utility in the class methodology to increase the likelihood that they will take advantage of the tool and improve their academic performance.

In terms of answering the research question posed, the results obtained show that the use of mixed methods allows the results of the quantitative phase to be complemented by observations from the qualitative phase. In this sense, in most cases, the qualitative data, which correspond to the students' perceptions, corroborate, and expand upon the results of the quantitative data. The agreement between the results of both phases allows for generating several hypotheses about the underlying reasons for the observed behaviors and the learning processes of the students, which are based on both quantitative and qualitative results. In other cases, the mixed approach reveals contradictions between the results of both phases (e.g., results of tool use), which allows for identifying topics of interest beyond the scope of the research and generating new questions that can be addressed in future works. In other words, the application of the framework presented in this paper demonstrated that a mixed methods approach to understanding the study question was superior to the use of a quantitative methodology alone.

Finally, it is worth noting that the application of the framework presented has some limitations, such as an imbalance in the dataset used in both the quantitative and qualitative phases. Specifically, the number of students with grades above the minimum passing grade is much higher than the number of students who fail the course, which could affect the magnitude of the correlations obtained differentiated by passing and failing categories. Moreover, there is a limitation associated with the high dispersion of the data on the total number of attempts made and the average time between attempts, due to the variety of activities carried out in the different groups of the programming course. Some instructors propose more hands-on workshops, reinforcement exercises, or projects with flexible deadlines, while others focus on assessing students' knowledge through short tests and exams, which usually have a limited time frame. This means that the behaviors and strategies that students use during their learning process can vary significantly depending on the type of activity they are exposed to. Finally, the students provided suggestions for improving the formative feedback, which should be considered to enhance the functionality and usability of the tool.

Hypothesis Generation

Based on the integration of results from both phases of the mixed methods approach used in the research and their interpretation, ideas for possible future work arise that can expand the discoveries of the current study. Firstly, it is possible to hypothesize that UNCode as a course tool may have a significant impact on the average final grades of students using the tool, particularly in a programming course. A comparative analysis between students using the UNCode platform and those enrolled in a similar course where the platform is not used could validate this hypothesis. To investigate this further, a quasi-experimental study design could be implemented with an experimental group consisting of students who use the tool and a control group consisting of students who do not use the tool.

On the other hand, the significant correlations evidenced can promote the design and execution of educational interventions within the course, corresponding to the final stage of the cyclic learning analytics methodology proposed by Carter et al. (2019). The development of interventions consists of making decisions in the studied educational context, where information, guidance, or feedback is shared with the students with the aim of positively influencing their behavior (Carter et al., 2019). In this context, it is plausible to hypothesize that an intervention designed to increase the visibility of error verdict descriptions, accompanied by additional instructions for error correction, could significantly improve the perceptions of students who perceive the feedback they receive as insufficient. Furthermore, suggesting the use of specific tools based on their functionality, such as recommending the use of Python Tutor to address runtime execution errors, may effectively encourage students to engage with platform tools, resulting in improved perceptions of the feedback process and possibly even improved academic performance. The impact of these interventions can also be evaluated through an experimental design that seeks statistical differences between a group that implements one of the interventions and a control group.

In the context of introductory programming education, AI/large language models have the potential to revolutionize teaching by enhancing the learning experience, providing personalized support, and enabling more efficient assessment and feedback mechanisms. Future research in this area is to implement the proposed framework on data from an introductory programming course using these models.

Conclusions and Future Works

This article proposes a sequential explanatory mixed-methods design for learning analytics, consisting of three main phases: (1) preparation, transformation, and analysis of quantitative data; (2) collection and content analysis of qualitative data; and (3) integration of results from both phases and discussion/interpretation of the findings. This framework was applied to historical quantitative and qualitative data from students' use of an automated feedback and evaluation platform for programming exercises in a programming course at the National University of Colombia. The answer to the research question posed corresponds to the fact that the results obtained demonstrate that the mixed methods effectively complement quantitative and qualitative data. Qualitative data, representing students' perceptions, generally support and extend the quantitative data. The consistency between the two phases allows hypotheses to be generated about student behavior and learning processes based on both types of data.

Specifically, the relationship between students' use of the programming tool and their academic performance was examined. Results indicate that students who expressed the highest level of agreement with the tool's usefulness for learning and who appreciated the ability to automatically evaluate their programs and receive feedback (qualitative data) tended to have better academic performance (quantitative data). This suggests that the formative feedback allowed students to identify errors and provided guidance for correcting the constructed program, which generated problem-solving skills and autonomous learning that enabled students to successfully complete course activities, which was positively reflected in academic performance. In addition, students who emphasized the benefits of the tool (qualitative data) achieved better academic performance (quantitative data). First, they found it valuable for identifying errors in their programs and providing corrective feedback. Second, the tool gave them the opportunity to practice programming autonomously and develop their problem-solving skills. The exercises provided were found to be challenging and stimulating, which motivated the students to learn and increased their curiosity. Students also appreciated the tool's objective and immediate grading system. All of this suggests that users who have a positive experience with the platform are more likely to recognize and take advantage of its benefits and achieve good academic performance.

The main contribution of this work is the proposed methodological framework for the application of learning analytics in computer programming courses, which is based on mixed methods and specifies activities from data collection, both quantitative and qualitative, to results integration and discussion. It is worth noting that the methodological activities are described in a general manner, providing a reference for future research in similar contexts. The use of mixed methods allows for the complementation, corroboration, or refutation of quantitatively evidenced results with qualitative data, and the generation of hypotheses about possible causes or explanations of students' behaviors. Specifically, the framework used in this approach helped to formulate hypotheses that describe different aspects of the learning processes that occur in a computer programming educational environment. Based on these hypotheses, several future research projects and works were proposed.

Although a limitation of the presented study is that the framework was only demonstrated in the context of its use for learning computer programming, we suggest that future research implement the proposed framework in different educational contexts and populations to strengthen the obtained results, complement the proposed methodology, or address identified issues. Potential lines of research to continue this work include (1) implementing the proposed mixed-method learning analytics methodology on a different population sample, such as students from other universities; (2) using techniques to correct unbalanced data sets, such as fine-tuning algorithms, resampling, or random over/under sampling in learning analytics studies; (3) analyzing students' interactions with the UNCode platform and their academic activities, such as exams, quizzes, workshops, projects, and assignments, in correlation with their activity grades rather than their final course grade; and (4) using the findings on students' behaviors and perceptions of the UNCode platform to design interventions that positively affect their academic performance, with an experimental design to statistically evaluate the effect.

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