Are We Ready for Problem-based Learning? A Proposal of Institutional Diagnosis in Computing Higher Education

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Abstract: In Computing Higher Education (CHE), the desired transformation of traditional teaching and learning methods, almost always based on the transmission of information and content-based curricula, has been the objective of several educational institutions that wish to combat students' demotivation and dropout. Among successful approaches, Problem-Based Learning stands out as one of the most effective and radical methods regarding pedagogical innovations. While the implementation of the PBL means a great opportunity to achieve better educational performance, it also represents many challenges that can only be managed if they are first known and understood. In this context, the motivation for this study comes from the following research question: "How to know if an institution at CHE is ready to implement the PBL?". As a response, an institutional diagnostic model regarding the adoption of PBL is proposed. From an opinion survey with 38 technical educational institutions in computing, involving 302 participants, the results showed that the model reached its objective, allowing the identification of favorable, warning, and critical points regarding the adoption of PBL in these institutions.

1 INTRODUCTION

In Computing Higher Education (CHE), the desired transformation of traditional teaching and learning methods, almost always based on the transmission of information and content-based curricula, has been the objective of several educational institutions that aim to prevent students' demotivation and dropout (Yang and Choi, 2017). There are diverse examples of successful approaches, in particular those using authentic problems, attractive technologies, and a learning environment that reflects the labor market to promote the engagement and motivation of the students (Babori et. al., 2016; Kemavuthanon, 2017; Martins et. al., 2018; Santos and Silva, 2018). Also, several solutions seek to systematize teaching and learning methods into methodologies, with concrete proposals to help transform the traditional classroom into a practical and stimulating environment. Thus, teaching methodologies such as Problem-Based Learning (PBL) (Yu, 2005; Jaryani et. al., Zhao and Liu, 2011; Panwong and Kemavuthanon, 2014; Ibrahim and Halim, 2014; Mäenpää et. al., 2017), and its variants like Project-Based Learning (Bell, 2010), Case-Based Learning (Srinivasan et. al., 2007) among others, have become popular in computing education, bringing important benefits such as increased engagement, motivation, and development of technical and non-technical skills so important to the professional life of the student. Born in the medical education and defined as "*a learner-centered constructivist method that uses real problems as a learning object*" (Savery and Duffy, 1994). PBL is considered one of the most effective and radical methods regarding pedagogical innovations. It advocates profound changes that involve the institution as a whole, transforming its learning environment, teachers' and students' attitudes, curricula, operational and managerial resources, infrastructure, assessment processes, relationships with the labor market, and, consequently, budget (Fink, Enemark and Moesby, 2002). While the implementation of the PBL means a great opportunity to achieve better educational performance, it also represents many challenges that can only be managed if they are first known and understood. In this context, it is necessary to understand the challenges faced by all stakeholders

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in the educational process based on PBL and raise the requirements to be adopted this approach effectively. With this objective, the NEXT (iNnovative Educational eXperience in Technology) research group has been investigated the use of the PBL approach in computer education for more a decade (Oliveira, Santos and Garcia, 2013; Santos et al., 2020), developing methodologies that can support the pedagogical team in adopting this approach. However, in recent consultancies in CHE institutions that wish to transform their curricula and traditional pedagogical proposals through the PBL, it was encountered an imminent difficulty: the institutions were not able to adopt the PBL and, even more critical, they did not know how to start. With this motivation, a master's research (Santos Filho, 2020) sought to investigate solutions that could help higher education institutions identify their ability to implement the PBL, making evident its favorable, critical aspects and warning signs. From a systematic literature review concerning PBL applied in computing education from 1999 to 2019 (Santos et al., 2020), several frameworks for applying PBL were identified, proposing the key elements for implementing the method and conducting the classroom approach as described in (Yu, 2005; Jaryani et. al., Zhao and Liu, 2011; Panwong and Kemavuthanon, 2014; Ibrahim and Halim, 2014; Babori et. al., 2016; Kemavuthanon, 2017; Mäenpää et. al., 2017; Martins et. al., 2018; Santos and Silva, 2018). But no solution was found focusing on investigating the situation of an educational institution regarding the requirements necessary for/adopting the PBL. So, the motivation for this study comes from the following research question: RQ - "*How to know if an institution at CHE is ready to adopt the PBL?*".

In this context, this study proposes a model of institutional diagnosis intending to investigate this situation, considering two target-public: *teachers/tutors*, giving their opinion on the essential elements for the adoption of the method under the pedagogical aspect, also reporting their perceptions related to students in general; *course coordinators/managers*, who have a more systemic view of the educational institution and, therefore, can contribute with their vision under structural and organizational aspects, complementary to the teachers' view. From these visions, the educational institution will be able to identify its strengths and improvement points regarding the implementation of PBL, supporting its decisions of changes within its pedagogical planning and educational strategy.

To report the early results of this research, this paper is divided into 6 sections. After this brief introduction, Section 2 presents the main PBL references used as the foundation of the model, highlighting concepts, challenges, and requirements for adopting this approach. Section 3 describes the research methodology and its steps. The institutional diagnosis model is presented in Section 4. To assess the practical applicability of this model, Section 5 describes the results and discussions of an opinion survey with 38 educational institutions in computing, which answered the proposed diagnosis involving their teachers and course coordinators' team. Finally, Section 6 discusses the conclusions and future work.

2 THEORETICAL REFERENCES

According to (Ribeiro, 2008), the PBL is a teaching and learning method that makes use of real problems to motivate students to learn concepts, procedures, and attitudes that will be important for their future performance as citizens and professionals. As emphasized in (Melo, 2013), the potential of the PBL in the teaching and learning process of students is capable of developing important skills such as self-confidence, problem-solving, and autonomy. Thus, the focus of the teaching process is the student, who is stimulated to learn more autonomously and cooperatively with his colleagues. The PBL method still requires a more active posture from students, choosing the best way to learn, conducting research, and using educational resources that go beyond the classroom. This also encourages students to reflect critically on what is proposed to solve the problem, important skills for future computer professionals in constant learning due to technological advances. In this context, the role of the teacher is to monitor and provide feedback on learning, in addition to identifying the difficulties encountered by students, facilitating and guiding the progress of their learning (Enemark, Kolmos and Moesby, 2006).

PBL follows some principles such as an authentic learning environment and simulation of the situation found in the professional environment, the use of real problems as a learning object, the monitoring of evaluation by continuous feedback (Ribeiro, 2008). In (Santos et al., 2013), ten principles were defined for the teaching of Computing that founded a methodology called *xPBL* (Santos et al., 2014), as shown in Figure 1.

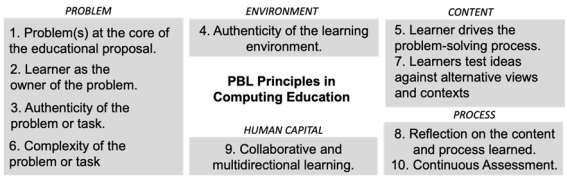

Figure 1: Ten PBL Principles and the xPBL elements.

The xPBL methodology defines five manageable elements for PBL planning: 1) Problem; 2) Learning Environment; 3) Human Capital, that includes students, pedagogical team and market partners; 4) Content, as a guide and support to solve problems; And 5) Processes, concerning educational objectives and assessment processes. These elements are aligned with the ten PBL principles (as shown in Figure 1) that are fundamental for the implementation of an authentic PBL in computer education.

2.1 Challenges in PBL

The adoption of the PBL approach, as it is not trivial, requires a series of changes, both in the attitude of teachers and students (Moesby, 2004; Santos and Silva, 2018; Aldabbus, 2018). According to (Moesby, 2004), it is common to evidence in the application of the PBL method the resistance of teachers, who often lack knowledge and experience in the teaching methodology, and for this, need to be trained to face the obstacles of the method.

Moreover, teachers should always be aligned with the PBL teaching process, considering that this approach requires a learning environment with a flexible curriculum geared to the demands of the professional market, in which the relevant issues are raised by the students and no longer by the teacher (Enemark, Kolmos and Moesby, 2006). As for the students, according to (Santos and Silva, 2018), some difficulties were observed in the application of the PBL method: a certain initial discomfort with the changes; lack of bibliographical research during the activities; lack of ability with technological resources; little involvement of the students in groups, and student priorities. However, there are also factors external to the learning environment that make it difficult to implement the PBL, as mentioned by the students, such as adequate time management, which causes a drop-in student performance and project quality (Hsu and Lin, 2016). In the application of the PBL, the dedication of students inside and outside the classroom is fundamental, and their active participation in the learning process.

It is also necessary to face many obstacles in the planning for the implementation of the PBL methodology, such as the development of problems or projects, the planning of classes with a new approach, the lack of technological tools and trained professionals to practice this method in the institution (Herold, 2019). The initial lack of security in the process of change to the PBL method needs to be overcome, as well as the difficulties of aligning the time between theory and practice, the adequacy of the curriculum, the availability of financial resources, the evaluation, and development of skills of the tutor teacher (Souza and Dourado, 2015). In (Aldabbus, 2018), the author reinforces these challenges emphasizing the lack of technology, flexible schedules, and absence of curriculum policy as difficulties in adopting the method. The study (Krusche et al., 2016) reports that there are institutional factors that hinder the adoption of the PBL method such as infrastructure, class planning, and didactic resources, in addition to an adequate environment for the development of team activities, technical-pedagogical support, and hiring of monitors/tutors.

2.2 Requirements to Apply PBL

To overcome the challenges of adopting the PBL, it is necessary to plan all the processes and resources before implementation, assisting in the correct use of the method, in the alignment of theory and practice, and respecting the principles of this approach (Santos et al., 2013). When planning to change a teaching and learning process, it is important to carry out a diagnosis in order to characterize the respective educational institution that will face the changes. Thus, it is possible to identify the main aspects required for the effective implementation of the approach.

Among the aspects to be analyzed, it is important to point out: collaboration between courses from a curriculum that allows the integration of knowledge acquired by students; a central committee for curriculum planning, to manage the content and topics to be addressed in the course; training of teachers to improve their didactics and learn new teaching strategies; planning of teaching in small groups and; availability of a period for study (Alshaye, Tasir, and Jumaat, 2019). The implementation of PBL also requires the understanding and participation of various actors (teachers, students, researchers, managers, real clients) who will be active in the processes, therefore the need to focus on team development and curriculum development of PBL (Fink, Enemark and Moesby, 2002; Koray and Koray, 2013). The PBL

curriculum should have a flexible format, be student-centered, be interdisciplinary, have real problems, and focus on research and investigation, promoting critical thinking and development of technical and non-technical skills (Hmelo-Silver, 2004; Melo, 2008). Content planning should focus on practical classes, with the learning process focused on solving problems that stimulate discussion, challenge students, and stimulate their creativity (Krusche, 2016; Barron and Wells, 2013).

Other prerequisites in the process of adopting the PBL are the provision of free space for self-learning, a review of the role of teachers and departmental autonomy, availability of financial resources to invest in infrastructure, and aligning student selection criteria to the profile expected by the PBL approach. Santos et al. (2020) reinforce that the implementation of the PBL method in an environment with traditional teaching triggers the need for a series of changes, such as the adaptation of the curriculum, the formatting and organization of the learning environment and the use of technologies.

PBL promotes many benefits for the student learning from the alignment of academic training with the requirements of the professional market (Herold, 2019). At this point, the PBL requires that the institution has approximation with companies in the labor market to provide teachers with new ideas and relevant problems to be addressed in the classroom.

There are organizations that perform PBL method consulting and analyze the institution at the organizational, pedagogical and educational level, thus supporting the design of a PBL-based curriculum, evaluation processes and, implementation of organizational and pedagogical aspects (Moesby, 2004). Moesby reports that many educational institutions analyze the needs of students today, and this brings about various changes at various levels: personal, organizational, and cultural. These changes require the development of an action plan, involving not only principals, but all those involved in the educational process, such as teachers, tutors, coordinators, and managers.

3 RESEARCH METHOD

This study has used a mix of methods, with emphasis on qualitative research and descriptive approach. According to Patton in (Patton, 2002), research is said to be qualitative when it aims to investigate what people do, know, think, and feel through data collection techniques such as observation, interviews, questionnaires, document analysis, among others. Conducted by the NEXT research group focusing on studies on the PBL approach applied to computing teaching, this research was motivated by direct observations in consulting activities to support educational institutions in the transformation of traditional methods to PBL, in general, carried out during the process of educational innovation and curriculum changes. At this time, an analysis of the institution is essential to identify the requirements for the implementation of PBL. Figure 2 shows the research steps and the main methods.

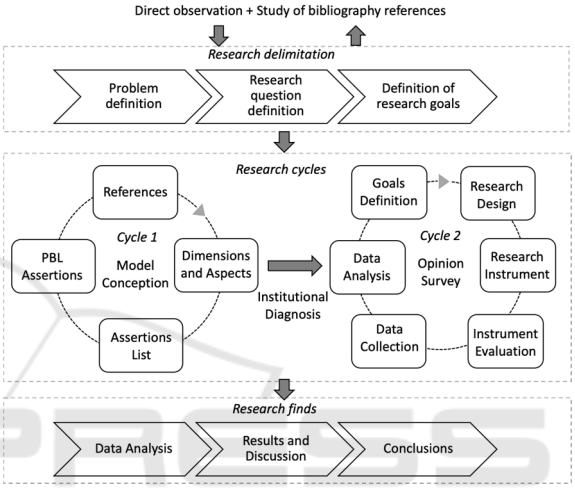

Figure 2: Methodological scheme.

After an ad hoc literature review seeking solutions to help this investigation, the central research question was defined: RQ - "*How to know if an institution at CHE is ready to adopt the PBL?*
To find objective answers, this research question was divided into three secondary questions:

- Q1 - *What are the favorable points for adopting the PBL?*
- Q2 - *What are the critical points for PBL adoption that can negatively impact its implementation?*
- Q3 - *What are the warning points that the institution needs to understand better to make new decisions?*

From these research questions, two objectives were defined: (1) the conception of a model to assess the ability to apply PBL and; (2) the application of this model in real educational institutions to verify its effectiveness. To achieve these objectives, two research cycles were designed, as shown in Figure 2.

The first cycle had focus on the "*conception of the institutional diagnosis*", which included searching the relevant literature on the adoption of PBL in the teaching computing (Oliveira, Santos and Garcia, 2013; Santos et al., 2020), understanding of the main challenges encountered by the institutions and the essential requirements for the successful implementation of PBL, as discussed in sections 2.1 and 2.2, respectively. From these references, three dimensions of the model and its aspects were identified:

- *Pedagogical*, with the five aspects Problem, Environment, Human Capital, Content and Process, based on the methodology cited in Section 2;
- *Structural*, which includes Infrastructure and Curriculum aspects, and;
- *Organizational*, with the Political and Evaluation aspects.

Besides, two target-public were defined: the teacher/tutor and the course coordinator/manager, both key actors in the process of transforming the pedagogical approach. At this point, the student inquiry was also considered, but it was decided to capture the students' perspectives from their teachers/tutors. As a result, a set of 85 assertions were identified, with respective rationales and literature references. After that, the assertions were analyzed by two PBL specialist, discarding those outside of the context and grouping others and, finally, defining 60 assertions distributed in two questionnaires of 30 questions each one, addressed to the two target-public. Each assertion has its rationale and literature references (URL in Appendix).

The second cycle was guided by the objective of applying the model. To do so, this research has used the opinion survey method proposed by Kitchenham and Pfleeger (2008), defined in six stages: Setting the objectives; Survey design; Developing the survey instrument (i.e. the questionnaire); Evaluating the survey instrument; Obtaining valid data and; Analysing the data. The research objective was to evaluate and identify the aspects required for the adoption of PBL in higher education institutions in computing, in both undergraduate and graduate levels, checking the current situation with teachers and course coordinators.

To create the research instrument, the questionnaires and assertions defined in Cycle 1 were analyzed by seven specialists (6 Ph.D. and 1 Ph.D. student, all with more than 5 years of experience in PBL) under the aspects of syntax, semantics, level of the relevance of the questions and completeness of the questionnaire. From this evaluation, some updates, groupings, and suggestions of new assertions were recommended: an assertion to verify if the self-regulation and metacognition of the students can be evidenced in the respective institution; an assertion on feedback in the evaluations of the teachers and other actors.

After the experts' evaluation, two forms (Google) were created, each directed to a type of participant (teacher or coordinator). The answers were based on Likert's ordinal scale: 1) *Totally Disagree*, 2) *Partially Disagree*, 3) *Neither Agree nor Disagree;* 4) *Partially Agree*, and; 5) Totally Agree.

For data analysis, consolidated charts were generated for each question, with the appropriate proportions of each answer chosen. For a qualitative discussion of the results, three status were defined: "*favorable*" (agrees), "*warning*" (neutral), and "*critical*" (disagrees), facilitating the analysis of responses towards the secondaries research questions and future decision making. The results of this assessment will be discussed in more detail in Section 5.

3.1 Limitations and Threats to Validity

It is important to highlight some limitations of this research. According to “Promoting Institutional & Organisational Development” guideline in (DFID, 2003), a diagnosis must be a thorough task, based on a careful selection of interested parties. However, preliminary or partial analysis in the first contact with the investigated institution can serve as a reference base to have a more comprehensive and in-depth diagnosis later.

Another important point is that an institutional diagnosis is focused on a particular organization, requiring time and effort to apply, discuss, and carry out future interventions. This research focused solely on the diagnosis application stage, using the opinion survey method for large-scale application, to understand its usefulness regarding the implementation of PBL, making evident the favorable, critical points and warning signs institutions.

Finally, to facilitate the processing of the data collected in the diagnosis, a Likert scale with five values from "totally disagree" to "totally agree" was used. However, the evaluation of the results adopted a qualitative interpretation of the data, identifying the favorable, critical points and warning signs, in response to the secondary questions Q1 to Q3. Thus,

no statistical method was applied in this case, which does not prevent it from being adopted in future works.

4 PBL INSTITUTIONAL DIAGNOSIS

The PBL institutional diagnosis is structured according to Figure 3, while Table 1 and 2 present the assertions for the Teacher/Tutor and Coordinator/Manager questionaries, respectively.

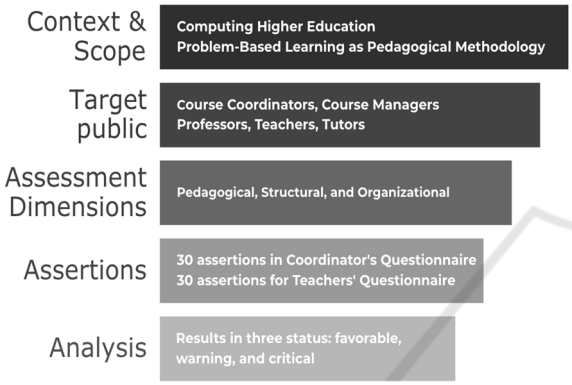

Figure 3: Structure of the Institutional Diagnosis.

The scope of the diagnosis is focused on computing courses, considering the PBL references used for its definition and the CHE context. Two questionnaires have created addressing collaborators of the educational institution in the role of teacher/tutor and coordinator/manager. Each questionnaire has 30 assertions, in the format of Google forms.

Regarding identification of the respondents, the following fields were also included: name, institution, position/function, e-mail, course modalities, course, duration (in hours), teaching methodology, PBL knowledge, and experience in PBL. The "course" and "duration" fields are only included in the teacher's form, and the "teaching methodology" field asks what type of methodology the teacher uses within three alternatives (traditional, active, and hybrid), while in the coordinator's form asks if the institution recommends any type of teaching methodology.

It is important to emphasize that the results of this diagnosis provide transparency about the situation of the institution from the perception of its employees. With this information, discussions, and referrals can be made, for example, regarding the training of teachers, approximation with market companies, or even acquisition of specific technologies.

Table 1: Teacher/Tutor Questionary.

PROBLEM	
A1	The activities developed in the computing course use real problems as a motivating element for student learning.
A2	Students in the computing course seek to take ownership of the problem to be solved, becoming responsible for the learning itself.
A3	The problems, problem situations, or hypotheses presented in the course are based on real contexts.
A4	Problems attributed to learners are stimulating as a challenge to reasoning.
A5	In the course, problems or problem situations have similar complexity to those found in real contexts.
A6	Students interact with real customers and users who have problems to solve.
ENVIRONMENT	
A7	The environment stimulates social skills and problem-solving required by the labor market.
A8	The students' learning environment seeks solutions to real client demands in order to reflect conditions similar to the professional market.
A9	Students demonstrate a professional attitude in the learning environment in order to maintain the authenticity of the labor market in the educational environment.
A10	The students' learning process is implemented in an environment that provides conditions for students to assume responsibilities assigned to certain functions and positions in the Computing.
A11	The physical and technological infrastructure of the learning environment stimulates and favors the execution of learning dynamics, group work, and collaborative activities.
A12	The learning environment fosters the understanding of the concepts that will be aimed at solving problems in the labor market context.
CONTENT	
A13	In the course of computing, there is alignment between theory and practice.
A14	There is integration between the courses in favor of the educational proposal of the curriculum.
A15	The content planned to be addressed is based on projects and practical activities.
A16	The content of the course is designed to be used as a guide and support for problem-solving, therefore flexible.
A17	The course structure is planned with content that will generate dynamics in student learning inside and outside the classroom.
A18	The course plan can be adjusted as the teaching methodology changes.

Table 1: Teacher/Tutor Questionary (cont.).

HUMAN CAPITAL	
A19	Teachers monitor the resolution of problems by students in order to stimulate resolution using interdisciplinary knowledge.
A20	In solving real problems, there is the participation of the real client to carry out the collaboration in the requirements of the problem.
A21	The students demonstrate to be active and autonomous in the construction of their knowledge from the solution of the proposed problems.
A22	In problem-solving tasks, teams or small groups are formed with 4 to 7 students to promote a greater contribution among members.
A23	The students' learning process has a multidirectional characteristic, that is, there is an effective relationship between students, teacher, tutor, and real client.
A24	The pedagogical coordination seeks, together with the teachers, to develop more collaborative and multidirectional projects for their students.
PROCESS	
A25	Teachers plan the content to be learned and evaluations should reflect on the content assimilated.
A26	Teachers carry out continuous evaluation and monitoring of the teaching and learning process, aiming to help students in their own reflection on learning from their difficulties and feedback.
A27	The institution seeks appropriate strategies for monitoring and evaluating student learning.
A28	In the teaching-learning process, characteristics of metacognition and self-regulation can be evidenced in students.
A29	The teachers evaluate the learning outcomes with the objective of following up the student in solving process, before putting it into practice.
A30	The educational planning meets the students' expectations regarding the objectives, goals, or expected results of the course.

Table 2: Coordinator/Manager Questionary.

INFRASTRUCTURE	
A1	The course environment (classroom, meeting room, etc.) and communication tools (email, instant message, groupware, etc.) facilitate interaction and collaboration of students.
A2	The course environment provides free space and sufficient time for self-learning by the student.
A3	There are sufficient materials, technological resources, and systems in the course to assist teachers during learning.
A4	Teachers demonstrate sufficient skills and capacity to perform activities as tutors.
A5	Teachers play a role as facilitators of learning and assist in the process of learner autonomy and independence.
A6	Tutors are available in the course to provide group mentoring.
A7	There is the role of the real client (in general, external collaborators), participating in the teaching and learning process, providing problems to be solved, and accompanying their resolutions.
A8	In the course, there are trained collaborators available to help in the tutoring process.
POLITICS	
A9	The institution usually conducts training for teachers and teaching staff for possible evolutions in the teaching process.
A10	The course involves the participation of companies in academic projects, to make the teaching and learning process closer to reality.
A11	In the student selection process, criteria such as interpersonal, autonomy, and creativity are considered, such as teamwork skills and student proactivity.
A12	Teachers easily plan, implement, and evaluate their courses.
A13	There is resistance from teachers when there are changes in curriculum or pedagogical methodology.
A14	There is resistance from students when there are changes in curriculum or pedagogical methodology.
A15	There is a culture of "learning by doing" in the institution, stimulating professional practice.
A16	Class planning is carried out collaboratively, involving the pedagogical team (e.g., teachers, tutors, real client).
A17	The institution's budget includes resources for practical approaches and continuous monitoring.

5 APPLYING PBL DIAGNOSIS: RESULTS AND DISCUSSION

The proposed diagnosis was applied in Federal Institutes of Education, Science, and Technology (FITs), institutions created by law 11.892/08 to promote basic, professional, and higher education, but also to offer education in different teaching modalities (Santos Filho, 2020). Each institute is led by a hierarchy of directors made up of rector, pro-rector, directors, coordinators, teachers, and

Table 2: Coordinator/Manager Questionary (cont.).

CURRICULUM	
A18	The adaptation of the course curriculum to a new pedagogical methodology may occur if it is necessary.
A19	The course brings interdisciplinarity and/or multidisciplinarity to the classroom.
A20	The curriculum is flexible, providing a consistent body of basic knowledge and autonomy to the student in the choice of their specialties.
A21	The class has a flexible schedule, being able to adjust according to the teacher's needs.
A22	There is a lack of alignment between the class load and the content to be taught by the teacher.
A23	The course curriculum encourages problem-solving and self-directed learning.
A24	The course is based on a curriculum that stimulates interdisciplinary and/or multidisciplinary practice.
EVALUATION	
A25	During the course, there is continuous monitoring and feedback from teachers to students.
A26	There is effectiveness in the course evaluation process through various evaluation criteria.
A27	The institution performs evaluations on the pedagogical methodology and the level of tasks required by the teachers.
A28	The evaluation system provides feedback on the teachers' work and the students' learning.
A29	The course's subjects allow for evaluations of the learning process and self-assessments of students.
A30	The institution performs evaluations regarding content, process, performance, satisfaction, and results generated from the course.

administrators. With a multi-campus structure of more than 661 units, there are 38 FITs distributed in various regions of Brazil based on professional and technical education. Although not all campuses offer courses in the area of computing, there are several courses in this area such as Computer Technician, Information Technology Management, Information System Analysis and Development, Bachelor of Computer Science, Databases, among others (Santos Filho, 2020).

All 38 FITs responded to the survey, totalling 302 respondents (222 teachers and 80 coordinators). Considering that teachers can teach in more than one academic level, most of them work in technical (92%) and higher (75%) courses, while a small portion of them work in graduate (14%) and extension (22%) courses. This scenario was similar to the coordinators with technical (60%), higher (49%), graduate (3%), and extension (8%). About 88% of the teachers stated that they apply active methodologies in their classes, while only 12% use traditional methodology. On the other hand, 62.5% of the coordinators answered that the institution where they work does not recommend a teaching methodology, while 22.5% answered that they recommend the active methodology and 15% indicate the traditional methodology. As for knowledge and experience in PBL, 57% of the teachers and 50% of the coordinators stated that they have median knowledge, with the level of experience also median even lower (42% of the teachers and only 30% of the coordinators).

5.1 Results of the Teacher Survey

Figure 4 shows an overall result from the 222 teachers.

On the "*Problem*" aspect, most stated using real, stimulating, and sufficiently complex problems as an element of study (favorable), but were uncertain about the appropriation of the problem-solving process by the student (warning).

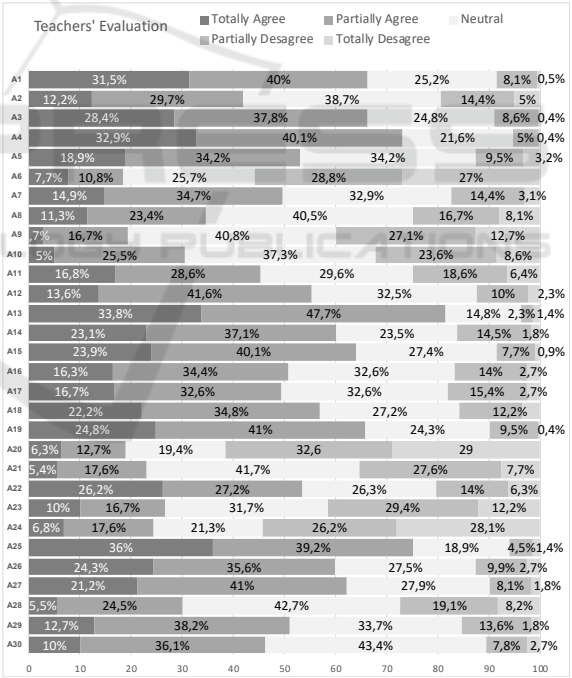

Figure 4: Teachers' results.

It was also evident the lack of interaction of students with real clients and users, compromising the authenticity of the learning environment (critical points). In PBL, real clients make it possible to build effective solutions through interactions that help students in the resolution process, providing feedback, and evaluating partial results (Santos et al., 2020).

Regarding the "*Environment*" aspect, teachers partially agreed that the environment stimulates social skills, solving problems required by the professional market and fostering important concepts (favorable), however, the authenticity of the environment was again questioned, considering that problems do not always reflect real market demands, compromising the student's professional posture (critical). According to (Bell, 2010), the PBL promotes the construction of knowledge and skills considered relevant to their professional practice, therefore, an inappropriate environment can impact this construction.

Concerning the "*Content*" aspect, as main favorable points are the alignment between theory and practice, integration between related courses, content approaches using practical projects, and appropriate subjects. Being institutions focused on professional education, it is understood that the course curricula have already been built for this purpose. Two points indicated a warning sign: flexibility of content in supporting the problem-solving process and content that promotes dynamic learning inside and outside the classroom. In PBL, the content needs to be flexible and focused on the problem-solving process (Krusche, 2016), with teaching that is much more "learning to learn" than "knowing a concept" that, far from practice, can easily be forgotten.

"*Human Capital*" was the most critical aspect. Although teachers follow the resolution of problems and stimulate group work with the formation of small teams of students (favorable), many showed uncertainty about the active posture and autonomy of students. Critical points are the lack of participation of the real client, a multidirectional relationship where everyone learns from everyone and stimulation of collaborative projects by the course coordinator.

Finally, the "*Process"* aspect showed as favorable points the content planning, evaluation, and continuous monitoring by teachers and institutions. However, warning signs for learning with characteristics of metacognition and self-regulation and a course planning that meets the expectations of the students. The characteristics of metacognition and self-regulation are present in the PBL approach, enabling the student to perform self-reflection and perform monitoring and evaluation of their learning (Santos and Silva, 2018).

5.2 Results of the Coordinators Survey

Figure 5 presents the overall result of the coordinators' responses.

In the "*Infrastructure"* aspect, the following are highlighted as favorable points: the environment and technological tools that facilitate interaction and collaboration; a free space and sufficient time for self-learning of the student; the existence of resources; teachers with skills for tutoring activities and teachers in the role of learning facilitators. The high bias in the agreement of these points and the rate of uncertainty in the first five assertions indicates a warning sign for many institutions. Critical points were the absence of tutors to support the teacher, collaboration with real clients, and training in tutoring activities.

Concerning the "*Politics*" aspect, favorable points are the realization of the training, ease in planning, implementing and evaluating, and the culture of "learning by doing" present in the institution. However, once again the lack of interaction with the labor market became evident, besides the absence of a student selection process more appropriate to the pedagogical approach and the collaborative planning of courses.

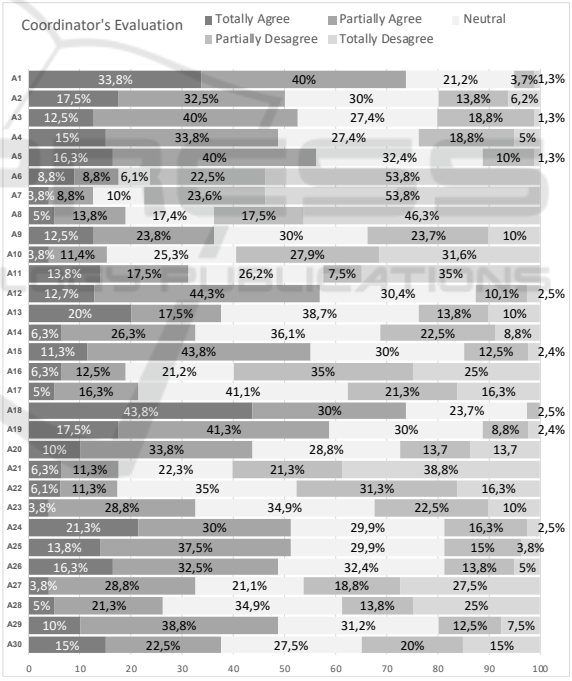

Figure 5: Coordinators' results.

It is also worth highlighting a warning regarding the resistance of teachers and students to changes in the curriculum or pedagogical methodology, and the need for a planned budget for educational practices.

Regarding the "*Curriculum*" aspect, the following points stand out as favorable: the adequacy of the curriculum, an interdisciplinary and multidisciplinary curriculum, and a flexible curriculum. However, the

result also shows a warning about the curriculum's ability to stimulate problem-solving and promote self-directed learning. Also, the lack of flexible hours and alignment of time to content was highlighted as negative points.

Finally, as for the "*Evaluation*" aspect, the following points stand out as favorable: monitoring and feedback, effectiveness and evaluations of the disciplines and the institution. Critical points were the absence of feedback from the evaluation system on the work of teachers and student learning, in addition to the lack of evaluation of teaching methodology and teacher performance.

5.3 General Discussion

Figure 6 presents an overview of the results from the teachers' questionnaire.

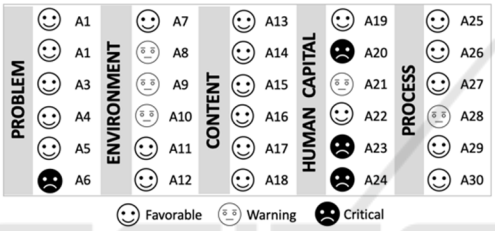

Figure 6: Teachers' results.

This figure shows a predominance of favorable points on the Problem, Content, and Process axis, with respect to the panorama of all the institutions involved in the survey. Considering the education purpose focused on professional performance, in general, these institutions have worked with real and relevant problems, with appropriate content for problem-solving, and have a student evaluation process. On the other hand, there was a greater predominance of critical points in the Human Capital axis, highlighting how impactful the PBL culture can be in its adoption. Based on this understanding, PBL training recommendations can be made regarding each actor's responsibilities and roles in the learning environment and the inclusion of new actors who can make a difference, such as real clients and tutors. It is worth noting the number of warning signs on the Environment axis, indicating that there are still many uncertainties regarding preparing the teaching and learning environment for PBL in these institutions.

Figure 7 presents an overview of the questionnaire results for the coordinators.

Comparing Figures 6 and 7, it can be clearly seen how much the structural and organizational aspects can negatively impact the PBL implementation, having as main axes of concern the infrastructure and the policy. Again, it became evident that it is necessary to work on the institution's PBL culture, involving educational managers and investing in teacher training to prepare institutions for the radical transformations that PBL brings. Other critical points also highlight the need for flexibility of the content, maintaining the alignment of theory with practice, and a special concern with the continuous evaluation process involving not only students, teachers, and coordinators.

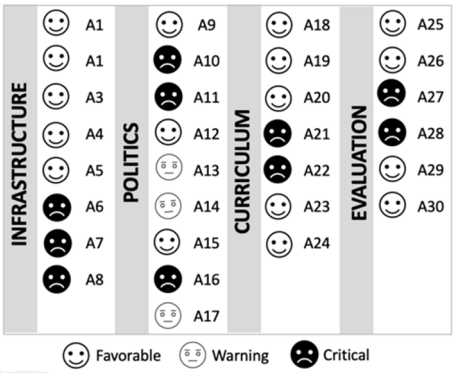

Figure 7: Coordinators' results.

Finally, from this kind of overview, a discussion with those involved in the diagnosis is recommended with each institution to raise the points of improvements and uncertainties, identifying and managing the risks for implementing the PBL.

6 CONCLUSIONS

Based on the motivation of how to assess whether an educational institution in the context of CHE is prepared to adopt the PBL, this study proposed an institutional diagnosis based on the pedagogical, structural and organizational dimensions, evaluating nine aspects with two groups of stakeholders: teachers/tutors and coordinators/ managers. To evaluate the model, this diagnosis was applied in 38 institutions of technical education in computing through an opinion survey, obtaining an overview of these institutions' situation with 302 respondents (222 teachers and 80-course coordinators in computing).

Due to these institutions' professional characteristics, several favorable points were identified, such as the use of real problems, curriculum, and student evaluation. On the other hand, critical points such as the academy's lack of interaction with the labor market, teacher training, and a more effective and ample assessment process were also highlighted. In particular, some warning

signs have also been identified regarding the suitability of the learning environment for PBL and the institutionalization of PBL culture.

The next steps are intended to make improvements in questionnaires and apply them to individual institutions, based on a careful analysis with their stakeholders. It is also intended to apply statistical methods for a more rigorous analysis.

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APPENDIX

A rationale and literature references for Teachers' and Coordinators' questionaries are available in: https://docs.google.com/spreadsheets/d/1E0fKh-NimU-OAhCed-geJ8bKpH8QzgmtqKD1VQzUupo/edit?usp=sharing