EUROPEAN SCIENCE EDUCATION RESEARCH ASSOCIATION ESERA

Utrecht University

ESERA Summer School 2022
Utrecht, The Netherlands
August 29 – September 3

Freudenthal Institute
Faculty of Science

ESERA Summer School 2022

eBook of Synopses

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1 Introduction

1.1 ESERA Summer School

The ESERA Summer School offers PhD students working in the field of science education research the possibility to present their work and to discuss its strengths and weaknesses in small groups of seven students and two experienced ESERA faculty members acting as mentors. In addition, the summer school offers a number of plenary lectures, workshops and poster sessions.

General information about the ESERA Summer School can be found on the website of ESERA, including a list of Summer School venues since the first one in 1993.

ESERA Summer School 2022

The ESERA Summer School 2022 will be held in the city of Utrecht in The Netherlands from August 29 to September 3, hosted by the Freudenthal Institute at the University of Utrecht.

The PhD students participating in the ESERA Summer School 2022 have been selected on the basis of the quality of the synopses they submitted in applying for taking part in the event. The quality of the synopses has been assessed by two reviewers – experienced science education researchers from within the ESERA community – working independently. The synopses have further been reviewed on whether the PhD project is at an appropriate stage (not too near the beginning or the end), such that the opportunities for discussion at the Summer School can contribute usefully to the students' work. Consideration has also been given to ensuring that a diversity of countries and fields of interest are represented at the Summer School.

The synopses are published as submitted in Section 3 of this *eBook of Synopses*, mostly without any editing. A revision of the submitted synopses on the basis of the reviewers' comments has not taken place. It was suggested to the students to use the reviewers' comments in preparing the presentation of their PhD study at the Summer School.

1.2 Reviewers

We acknowledge the following reviewers for the ESERA Summer School 2022 for the time and effort they invested in assessing the quality of the submitted synopses and in giving their constructive comments:

Alexander Kauertz, Allison Gonsalves, Andreas Nehring, Ann Childs, Antti Lehtinen, Antti Laherto, Blanca Puig, Christina Siry, Claudia von Aufschnaiter, Costas Constantinou, Digna Couso, Georgios Ampatzidis, Giulia Tasquier, Isabel Martins, Judith Hillier, Justin Dillon, Lucy Avraamidou, Lukas Rokos, Magdalena Kersting, Maria Gabriela Lorenzo, Mariona Espinet, Martin Rusek, May Lee, Nathália Azevedo, Nicole Graulich, Nicoleta Gaciu, Pasi Nieminen, Patricia Patrick, Radu Bogdan Tomu, Renee Schwartz, Sevil Akaygun, Veli-Matti Vesterinen, Yakhoub Ndiaye, Ying-Chih Chen.

Review Criteria

All submitted synopses have been reviewed on the following seven criteria on a four-point scale from Poor (significant weaknesses or lacking information), Fair (needs improvement), Good (meets the criterion) to Excellent:

- Outline of the focus of the study (e.g. topic, problem or issue, educational context).
- Discussion of the literature and/or the background ideas relevant to the study.
- Statement of the research question(s) the study is aiming to answer.
- Outline of the research design, methodology and method(s) to collect and analyse data.
- Indication of the nature and extent of the data collected so far, discussion of data analysis undertaken so far, and preliminary findings (bearing in mind the current stage of the study).
- Use of academic conventions in references and citations.
- Coherence and clarity of the synopsis as a piece of academic writing.

1.3 Sponsors

We acknowledge our sponsors of the ESERA Summer School 2022 for their generous contributions that have made the event possible:

- ESERA – Accommodation and travel expenses of staff members.
- Freudenthal Institute, University of Utrecht – Meeting rooms, ICT and administrative facilities and support, Helpdesk master students.
- WND Foundation – Welcome Reception, Excursion and Farewell Party.

2 Program

2.1 Venues and Transfers

Meeting rooms

All meeting rooms will be situated in the *Buys Ballot building* at the Science Park of the University of Utrecht.

Accommodation

Most students will be hosted at the Stayokay Hostel Bunnik in 4-, 6- and 8-person dormitory-type rooms with bathroom.

Stayokay Hostel Bunnik: An impression of its buildings, and the rooms for the students' overnight stay.

It has to be noted that the accommodation at the hostel is rather sober, and requires bringing your own towel(s). The overnight stay in 4- to 8-person rooms can be seen as a good opportunity for getting-to-know each other and for networking. And to futher facilitate such interaction: the hostel's bar will be open until 12 midnight.

Staff members and some students will be hosted in single rooms at the Postillion Hotel Bunnik.

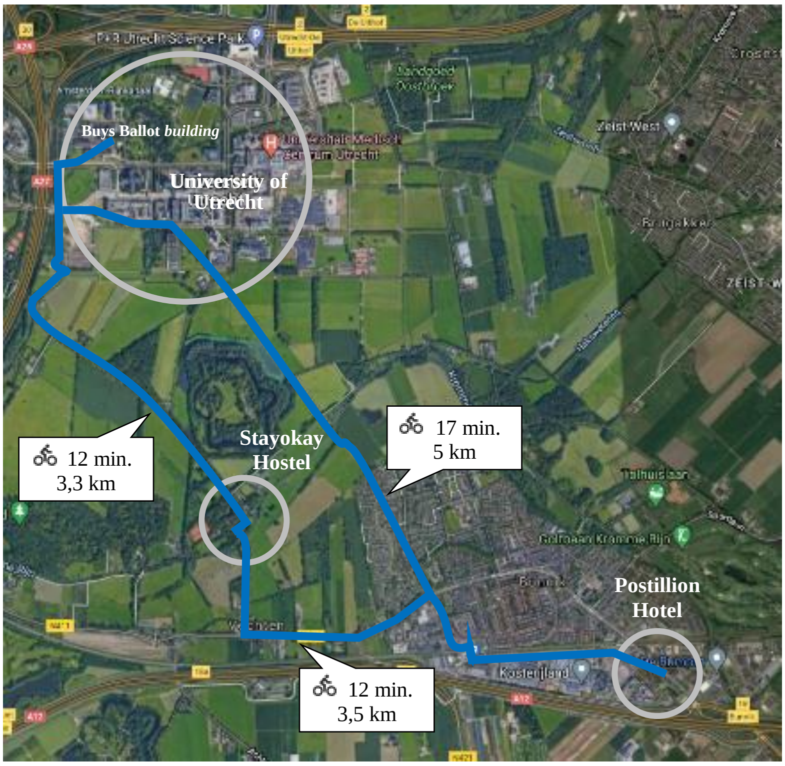
Postillion Hotel Bunnik

Transfers

Transfers between the hostel, the hotel and the university for most students and staff members will be by individual rental bike, with transfer times of approximately 15 minutes: see the *Map of the Area* below for an idea of the transfer routes and distances. Some participants have decided to walk instead of using the bike. Transfers by car or passenger van will be organised for those who, for health or other valid reasons, are unable to ride a bike or walk.

All transfer routes consist of roads with low traffic intensity or cycle paths. A bike-riding clinic will be organised on Monday after arrival at the hostel or the hotel for those who have indicated a need for that.

All participants should have rain gear with them to keep dry, and a small handy backpack for transporting belongings while cycling or walking.



Map of the area: transfer routes and distances.

All participants should make sure that they are sufficiently insured against medical expenses and accidents, and against theft of their possessions. The Summer School organizers are not liable for this type of cost.

2.2 Travel

The Summer School venue can be reached by international trains to Utrecht Central Railway Station, followed by a regional bus trip of approximately 20 minutes and some additional walking. If traveling by plane, there are local trains from Schiphol Airport to Utrecht.

International trains to Utrecht CS

The website of the University of Utrecht offers a comparison of travelling by train or plane with respect to travel times, CO_2 emissions and number of transfers when travelling from Utrecht to a number of European cities (which, of course, also works 'the other way round'): The Train Zone map.

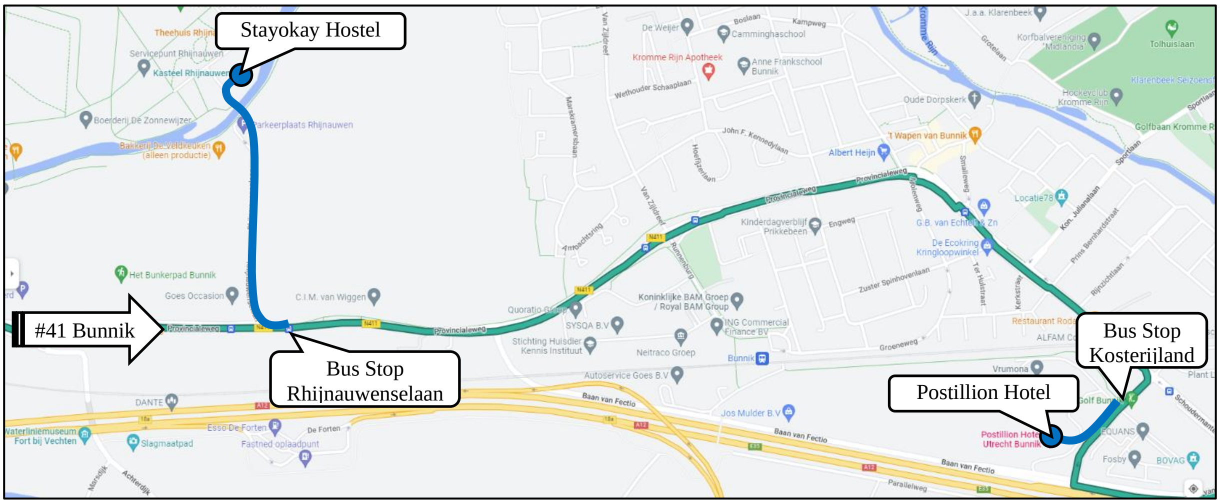
Schiphol Airport to Utrecht CS

From the Schiphol Airport Railway Station, about five IC Intercity trains per hour depart during the day in the direction of Utrecht. With this train journey you travel without $C0_2$ emissions: the train runs on wind power. Traveling time is about 30 minutes. Single trip ticket price is roughly € 10,-. Tickets can be bought at the station's NS Ticket Office or ticket vending machines (cash, PIN bank cards and credit cards: V PAY, Maestro, Mastercard, Visa and American Express). See also the video [How to buy a train ticket in The Netherlands](#).

Train and bus ticket vending machines (left and right, respectively)

Utrecht CS to Stayokay Hostel and Postillion Hotel

From Utrecht Central Railway Station, about five regional buses per hour depart during the day in the direction of Bunnik. Departure: CS Utrecht Jaarbeursplein, Platform C3. Bus line 41, direction Wijk bij Duurstede. Traveling time is about 15 minutes for the Stayokay Hostel and 20 minutes for the Postillion Hotel. This is a 3-4 zone distance, with a single trip ticket price of roughly € 5,-. U-OV Travel tickets can be bought at the U-OV Tickets & Service Office near the exit of the railway station's main hall or ticket vending machines (cash, PIN bank cards and credit cards: Visa and Mastercard). The 1.5 hour validity of the 3-4 zone U-OV Travel ticket starts immediately after buying the ticket. Tickets are also sold by the bus driver (no cash, PIN bank cards only).



Line #41 bus stops and walking routes to the Stayokay Hostel and the Postillion Hotel.

Stayokay Hostel: get off at the bus stop *Rhijnauwenselaan* in Bunnik and take a 10 minute walk to the Hostel (blue line on the map).
Postillion Hotel: get off at the bus stop *Kosterijland* in Bunnik and take a few minutes' walk to the Hotel (blue line on the map).

Public Transport: E-Ticket

Want to have the ticket for your entire train (NS) and/or bus (U-OV) journey in The Netherlands in one app? Purchase your e-ticket using the 9292 app.

Travel by car & carpooling

Of course, travelling by car is also a possibility, and carpooling with other participants could be a good way to start Summer School networking. Parking at the Stayokay Hostel is possible, but the number of parking places is limited. Parking at the Postillion Hotel is no problem. However, parking at the university can be difficult and is certainly rather costly.

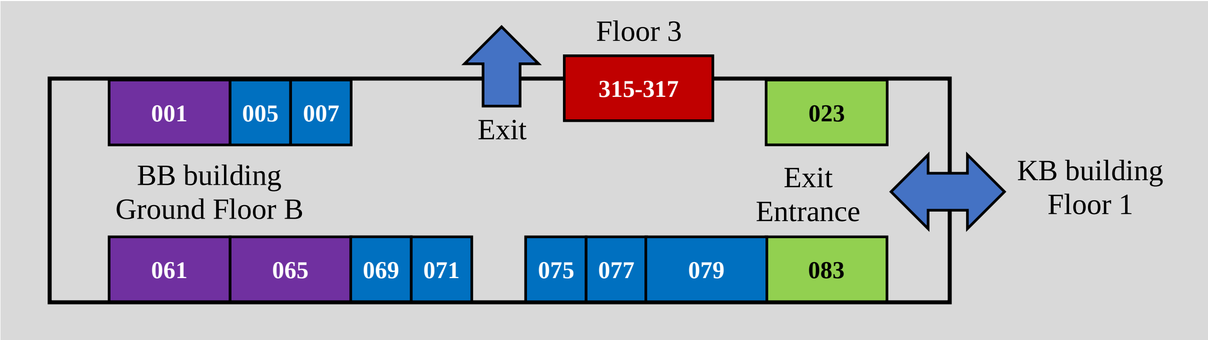
Addresses

Stayokay Hostel: Rhijnauwenselaan 14b, 3981 HH Bunnik, The Netherlands | Phone +31 30 656 1277 | E-mail bunnik@stayokay.com.
Postillion Hotel: Baan van Fectio 1, 3981 HZ Bunnik, The Netherlands | Phone +31 30 656 9222 | E-mail hotel.bunnik@postillionhotels.com.

2.3 Time Schedule

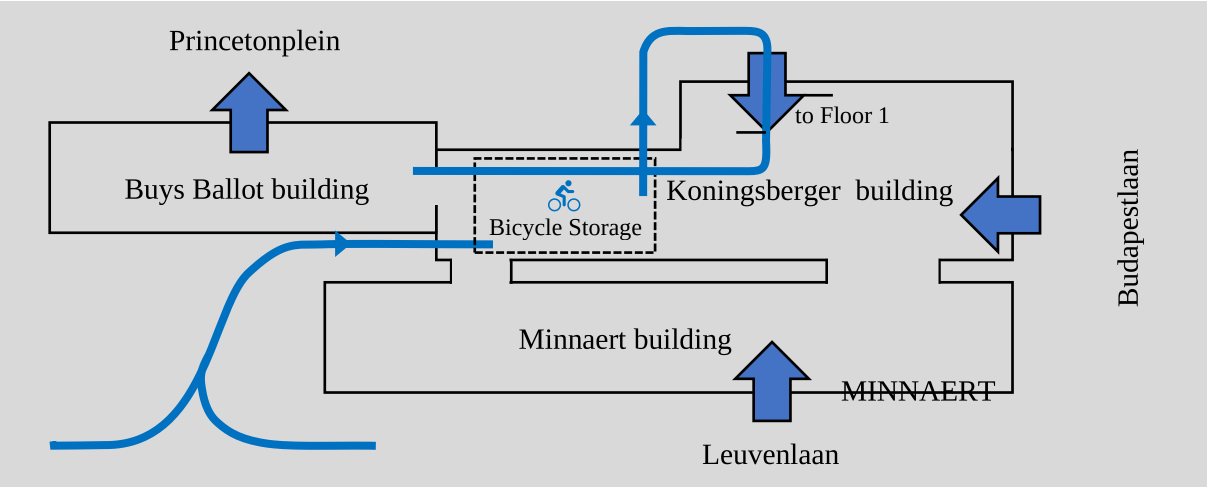
The Time Schedule of the Summer School includes four plenary lectures, three rounds of three workshops, eight mentor group meetings, and two poster sessions. Further information about these parts of the program is given in Sections 2.4, 2.5, 2.6 and 2.7, respectively.

CET	Monday, August 29	Tuesday, August 30	Wednesday, August 31
07.30 – 08.00		Breakfast	Breakfast
08.00 – 08.30			
08.30 – 09.00		Bike Transfer > UU	Bike Transfer > UU
09.00 – 09.30		Mentor Group Meetings	Mentor Group Meetings
09.30 – 10.00		(1)	(3)
10.00 – 10.30			
10.30 – 11.00	Arrivals and Registration	Break	Break
11.00 – 11.30	Workshop Subscription	Plenary Lecture:	Plenary Lecture:
11.30 – 12.00		L1 BBb 315-317	L2 BBb 315-317
12.00 – 12.30		Lunch UU	Lunch UU
12.30 – 13.00			
13.00 – 13.30		Mentor Group Meetings	Mentor Group Meetings
13.30 – 14.00		(2)	(4)
14.00 – 14.30			
14.30 – 15.00		Break	Break
15.00 – 15.30		Workshops:	Workshops:
15.30 – 16.00	Bike Clinic	W1 BBb 001	W3 BBb 061
16.00 – 16.30		W2 BBb 065	W4 BBb 065
16.30 – 17.00		W3 BBb 061	W5 BBb 001
17.00 – 17.30		Poster Session:	Poster Session:
17.30 – 18.00		(1) BBb 023 & 083	(2) BBb 023 & 083
18.00 – 18.30	Opening Ceremony		
18.30 – 19.00	Welcome Reception	Bike Transfer >Stayokay	Bike Transfer > Stayokay
19.00 – 19.30	Dinner Stayokay	Dinner Stayokay	Dinner Stayokay
19.30 – 20.00			
20.00 – 20.30			
20.30 – 21.00			
21.00…			



Floor Plan of the *Buys Ballot building* (BBb) with the rooms for the Plenary Lectures (Floor 3), and for the Workshops, Mentor Group Meetings and Poster Sessions (Ground Floor B). Entrance through Floor 1 of the *Koningsberger building* (KBb).

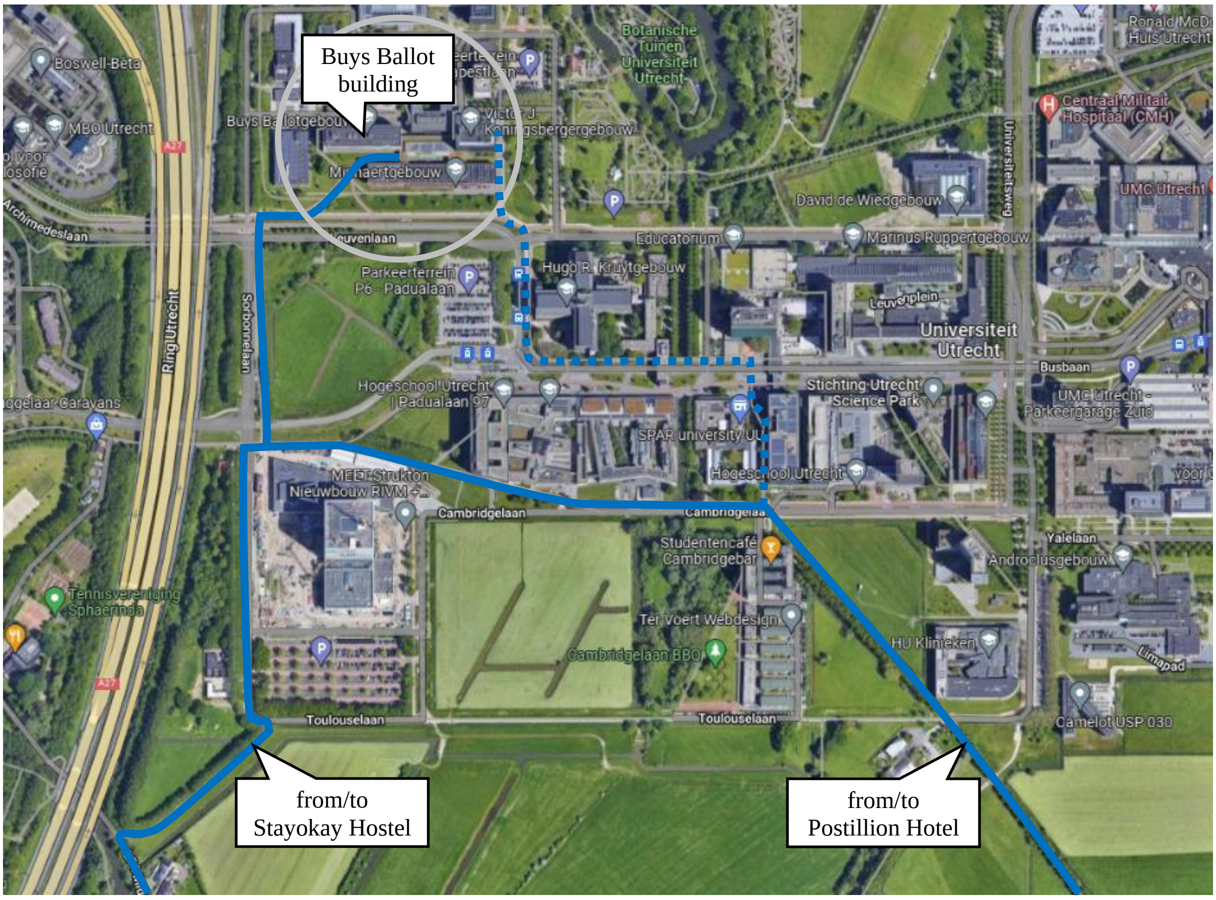
CET	Thursday, September 1	Friday, September 2	Saturday, September 3
07.30 – 08.00	Breakfast	Breakfast	Breakfast
08.00 – 08.30			
08.30 – 09.00	Bike Transfer > UU	Bike Transfer > UU	Student Departures
09.00 – 09.30	Mentor Group Meetings	Mentor Group Meetings	Staff Meeting
09.30 – 10.00	(5)	(7)	
10.00 – 10.30			
10.30 – 11.00	Break	Break	Staff Departures
11.00 – 11.30	Plenary Lecture:	Plenary Lecture:	
11.30 – 12.00	L3 BBb 315-317	L4 BBb 315-317	
12.00 – 12.30	Lunch UU	Lunch UU	
12.30 – 13.00			
13.00 – 13.30	Mentor Group Meetings	Mentor Group Meetings	
13.30 – 14.00	(6)	(8)	
14.00 – 14.30		Reflection and Evaluation	
14.30 – 15.00	Break	Break	
15.00 – 15.30	Bike Transfer > Stayokay	Workshops:	
15.30 – 16.00	& Postillion	W1 BBb 001	
16.00 – 16.30	Excursion	W4 BBb 065	
16.30 – 17.00	Utrecht Time Machine	W6 BBb 061	
17.00 – 17.30		Group Presentations	
17.30 – 18.00			
18.00 – 18.30		Closing Ceremony	
18.30 – 19.00	Dinner	Bike Transfer > Stayokay	
19.00 – 19.30	Pizzeria La Fontana	Dinner Stayokay	
19.30 – 20.00		Farewell Party	
20.00 – 20.30			
20.30 – 21.00			
21.00…			



Entrance to the *Buys Ballot building* is either through the *Koningsberger building* or the *Minnaert building* on Floor 1.The Bicycle Storage is on the Ground Floor below part of the *Koningsberger building*. From the Bicycle Storage, the easiest way to enter the *Koningsberger building* is through the side entrance as indicated by the blue line. Then go to Floor 1 and follow the signs to the *Buys Ballot building*.

Addresses

[Buys Ballot building](#): Princetonplein 5, 3584 CC Utrecht, The Netherlands
[Koningsberger building](#): Budapestlaan 4a-b, 3584 CD Utrecht, The Netherlands
[Minnaert building](#): Leuvenlaan 4, 3584 CE Utrecht, The Netherlands



Biking (blue lines) and walking (dotted blue line) routes from/to the *Buys Ballot building* on the Science Park of the University of Utrecht.

2.4 Plenary Lectures

The table below gives an overview of the interactive plenary lectures at the Summer School, followed by the abstracts of these lectures.

Day	L	Lecturer	Title
Tuesday, August 30	L1	Nicoleta Gaciu	Visualisation and Analysis of Quantitative Data
Wednesday, August 31	L2	Martin Rusek	"How can we see through students' eyes?": Overview of Contemporary Use of Eye-Tracking in Science Education
Thursday, September 1	L3	Isabel Martins	Science Education through the Epistemological Lenses of Social Theories of Discourse
Friday, September 2	L4	Veli-Matti Vesterinen	Climate Change Competencies in Science Education

All lectures will be held in the *Buys Ballot building*, room 315-317 (Floor 3), 11:00 – 12:00 CET.

2.4.1 Plenary Lecture L1

Tuesday, August 30, 11:00 – 12:00 CET | Room 315-317

Visualisation and Analysis of Quantitative Data

Nicoleta Gaciu
Oxford Brookes University, UK

Understanding quantitative data in educational research is not only about collecting and analysing quantitative data to find answers to research questions or to test hypotheses, but is also crucial for understanding and critiquing published research results in the form of research papers, projects and dissertations. Analysis of quantitative data typically requires the use of multiple statistical and computational techniques before reaching any conclusions. However, using only these techniques is not enough; they just make the calculation and do not interpret the data. The statistical analysis goes hand-in-hand with the graphical display of data because it helps with the process of understanding and communicating results and conclusions in useful ways. Different types of scale of measurement require different types of visualisation and can be quickly done by the graphical representation of data before any computational analysis. Besides, graphs help us not only perceive some features of quantitative data but also allow us to check if the assumptions made for a statistical test are correct.

The interactive plenary session on 'Visualisation and Analysis of Quantitative Data' aims to present, in plain language, the essential features of several methods for visualising and analysing quantitative data in educational research and to encourage participants to engage actively in discussing and analysing examples from published educational research. The selection of statistical tests is based on a combination of several assumptions about the parameter of the population from which a sample is drawn and on several selection decision-making strategies, such as types of analysis, scales of measurements, distribution of data, and types of samples and variables. In this session, I will demonstrate, for example, strategies for choosing the right statistical tests for finding the differences between samples or relationships between variables. In addition, many practical tips are offered on how to interpret the test results correctly. Furthermore, attention is given to the link between quantitative data analysis and methodology.

2.4.2 Plenary Lecture L2

Wednesday, August 31, 11:00 – 12:00 CET | Room 315-317

"How can we see through students' eyes?": Overview of Contemporary Use of Eye-Tracking in Science Education with Examples of our own Research

Martin Rusek
Charles University, Czech Republic

Modern, evidence-based science education heavily depends on data from various tools describing students' behaviour or performance. Until recently, however, the data were more or less burdened by the fact that students remained a black box providing some responses either in a written or an oral way, eventually behaving in a certain way which researchers anyhow captured. Modern technology has brought another valuable tool which may truly cause revolution in the field of education research. With the use of eye-tracking camera or goggles, we can literally see through students' eyes. Eye-tracking (ET) has then become a very valuable asset which has the potential to change education from scratch.

In this plenary, the ET method will be briefly explained together with its rapid development. Its procedure and combination with other methods will be explained so that the audience gains general understanding of ET's potential. In addition, preliminary results of a systematic literature review on the use of eye-tracking in science education will be presented. The results are divided into several thematic parts: research design (between or within-subject, assessment), performance measures (problem tasks, pre- and post-test, response accuracy, mind-wandering signals etc.), the most addressed topics (or reading of learning material, scientific representations, practical work assessment, problem-solving skills evaluation, video instruction evaluation) or the most common ET metrics (total fixation duration, fixation count, time to first fixation, number of saccades, saccade length, reading and re-reading time or scan-path pattern). Each will be briefly introduced with one example left for the audience to analyse on their own to get the idea about the data ET provides and also about its potential and limitations. At the conclusion, future directions of ET will be predicted and further discussed with the audience. They will be challenged to find the use in their field or evaluate to what extent their own theses' research design might benefit from the use of ET.

2.4.3 Plenary Lecture L3

Thursday, September 1, 11:00 – 12:00 CET | Room 315-317

Science Education through the Epistemological Lenses of Social Theories of Discourse

Isabel Martins
Federal University of Rio de Janeiro, Brazil

Scientific knowledge is an undoubtedly important mediating instance of peoples' social lives and Science Education (SE) is instrumental in articulating conceptual, epistemological, pedagogical, socio-political and historical aspects of this knowledge. Many of SE contributions derive from research that is grounded on language-based documents – such as textbooks, popular science texts, curriculum policy documents – or on verbal data records – such as oral interviews, written journals or classroom interactions. More than often though, language is treated unproblematically with respect to the ways through which relationships between linguistic and social dimensions of discourse related data can shape identities, positionings and understandings of science.

In this presentation, I will discuss the contribution of Social Theories of Discourse to analyse both conjunctural and linguistic aspects of science matters and their representations in social life. The discussion explores ontological, epistemological and methodological aspects of language based research and is framed in contexts related to scientific literacy research, such as social participation and decision making. Examples to be discussed include analyses of ways through which the concepts of literacy, citizenship and social justice are signified (1) in curriculum documents, textbooks and teacher education programs, and (2) in discursive interactions held by members of communities of practice involved in projects that deal with health and environmental issues.

2.4.4 Plenary Lecture L4

Friday, September 2, 11:00 – 12:00 CET | Room 315-317

Climate Change Competencies in Science Education

Veli-Matti Vesterinen
University of Helsinki & University of Turku, Finland

Alongside biodiversity loss, inequality and depletion of natural resources, climate change mitigation is one of the urgent and global challenges humanity is currently facing. It is described as wicked problem that has dire consequence for the wellbeing of humans and no simple solutions in sight. As climate expertise is urgently needed in all sectors of the society, education – and especially science education – is usually seen to play a crucial part in climate change mitigation. But as the research and practice of environmental and sustainability education has shown, it is not clear how education can and should contribute to solving such wicked problems. Consequently, climate education is also often considered a wicked problem.

My plenary talk is based on the results of a transdisciplinary research project combining expertise of climate scientists, science educators and educational psychologists. The research group examines what are the needed competences in the society to efficiently mitigate and adapt to climate change, and how these competencies are learned and taught throughout the educational system. The climate competencies described in recent research as well as national and international policy documents go beyond the climate-related knowledge and include for example problem solving and future thinking skills, values, identity, future orientation as well as hope and other emotions. Amongst the proponents of climate education, it is quite widely agreed that reaching such competencies will require systemic changes on all levels on education.

Based on the results from classroom level studies in upper secondary and higher education, our results highlight the focus on the agency of students as well as teachers. Supporting climate action demands that both students and teachers become agentic concerning climate mitigation. As top-down efforts often lead to a reactive agency, we propose and discuss our experiences of approaches, which seek to strengthen the student and teacher autonomy in climate education and support more proactive forms of agency.

2.5 Workshops

The table below gives an overview of the workshops at the Summer School, followed by the abstracts of these workshops.

Day	W	Workshop Leader	Title	Room
Tuesday, August 30	W1	Justin Dillon	Writing, Publishing and Reviewing Research in Science Education	001
	W2	May Lee	Qualitative Data Analysis	065
	W3	Robert Evans & Alexander Kauertz	PhD Research as Seen from the Perspective of the Toulmin Argumentation Model	061
Wednesday, August 31	W3	Robert Evans & Alexander Kauertz	PhD Research as Seen from the Perspective of the Toulmin Argumentation Model	061
	W4	Reneé Schwartz	Academic Writing: What is the problem?	065
	W5	Radu Bogdan Tomu	Choosing the Right Data Collection Instrument for your Research: Understanding Validity and Reliability of Measurement Instruments	001
Friday, September 2	W1	Justin Dillon	Writing, Publishing and Reviewing Research in Science Education	001
	W4	Reneé Schwartz	Academic Writing: What is the problem?	065
	W6	Antti Lehtinen	Science Education Research(ers) and Professional / Disciplinary Identity	061

Please note that workshops 1, 3 and 4 will be held twice on different days. And also note that workshops 2 and 4 require that participants bring some documents related to their PhD study as an input to the workshop.

All workshops will be held in the *Buys Ballot building*, Rooms 001, 061 and 065 (Ground Floor), 15:00 – 17:00 CET.

2.5.1 Workshop W1

Tuesday, August 30 & Friday, September 2, 15:00 – 17:00 CET | Room 001

Writing, Publishing and Reviewing Research in Science Education

Justin Dillon
University of Exeter, UK

This highly interactive workshop, which has evolved over a number of summer schools, aims to demystify an essential aspect of being an academic and a scholar (we'll discuss the difference between the two terms). We'll begin by thinking about why we write and who we write for. Next, we'll look at deciding what and where to publish and at the murky depths of journal metrics. You will develop a better understanding (and, possibly, a healthy scepticism, of) impact factors, rejection rates and decision times. We will then look at the submission process and at how papers are reviewed. We discuss the criteria that reviewers use and consider the advantages and the disadvantages of the process. This part of the workshop should help you to feel more confident about submitting papers for review. Finally, we'll look at the rise of predatory journals.

By the end of the session, you should have developed an understanding of what's involved and, more importantly, a plan for where and what you might publish in the short, medium and long-term.

2.5.2 Workshop W2

Tuesday, August 30, 15:00 – 17:00 CT | Room 065

Qualitative Data Analysis

May Lee
University of Groningen, The Netherlands

In this interactive workshop, we will introduce some key strategies and tools for qualitative data analysis and then work through a part of your research project to identify strategies and tools for qualitative data analysis that can help move you toward your research goals. To get the most out of this workshop, *please bring your research question(s), outline of the research design/ methodology/method(s) used to collect/analyse the data, data to be analysed, and one or two questions you might have about your data analysis.*

The workshop will start with a short overview of strategies and tools for qualitative data analysis. Most of the time will be spent on guided peer-analysis of your data in small groups (pre-determined by workshop leader, based on similarities in the data sources/analytic methods described in the submitted proposals). At the end of the workshop, you will have a chance to share some of your findings and network with your peers for possible future collaborations.

2.5.3 Workshop W3

Tuesday, August 30 & Wednesday, August 31, 15:00 – 17:00 CET | Room 061

PhD Research as Seen from the Perspective of the Toulmin Argumentation Model

Robert Evans & Alexander Kauertz
University of Copenhagen, Denmark & University of Koblenz-Landau, Germany

When publishing or presenting our research we need to establish a good link between our local project and the bigger picture. The idea of the workshop is to experience how it feels to make sense of data from these two different points of view: one up close and the other as an overview. For the close look, participants will be given analysed data from a science museum study and asked to discover if all of the data's potential has been realised. As students work through strategies for getting the most out of this example, they reflect on applications to their own work.

Then the workshop will take a meta-view of this museum study and map it using a theoretical model. With this example in hand, participants will map their own PhD research. This mapping activity should help establish a link in PhD research projects between theoretical backgrounds, literature review, empirical data, research questions and methods of analysis. This overview can then help participants decide on appropriate methods for data analysis, how to use data to underpin assumptions and interpretations, and to decide what results are important to present.

2.5.4 Workshop W4

Wednesday, August 31 & Friday, September 2, 15:00 – 17:00 CET | Room 065

Academic Writing: What is the problem?

Reneé Schwartz
Georgia State University, USA

Having trouble getting started with that research paper or proposal? Do you have to edit down an article to fit a page limit? Is the reviewer missing your point? These are all common issues with academic writing. The answers usually start with looking at the problem statement. The problem statement is how the audience gets introduced to the research.

This workshop will provide an overview of generating an effective and concise problem statement for research. A well-written problem statement captures the attention of the audience and grounds the research in solid literature and recommendations, making the significance of the research evident from the beginning of the paper. Using prompts and students' own research writings, students will (1) identify elements of a problem statement, (2) evaluate and revise problem statements, and (3) generate their own problem statement relevant to their research. The workshop will also include tips and practice in editing academic writing for clarity and conciseness. Students will be supported in the preparation of a writing piece for submission to a conference or a journal. *Students should bring samples of their writing for review and revision*.

2.5.5 Workshop W5

Wednesday, August 31, 15:00 – 17:00 CET | Room 001

Choosing the Right Data Collection Instrument for your Research: Understanding Validity and Reliability of Measurement Instruments

Radu Bogdan Toma
University of Burgos, Spain

The number of available measurement instruments (e.g., scales, questionnaires, inventories, tests) in science education has grown dramatically over the last few decades. Consequently, deciding which instrument to use has become a major challenge. Research conducted with measures of unknown or poor validity and reliability can waste resources and raise ethical dilemmas. When instruments lacking validity and reliability evidence are used, the trustfulness of the findings is at stake and remains unclear. Therefore, it is paramount for science education researchers to develop an understanding of what constitutes good measurement practices and what aspects should be considered when selecting an instrument for measuring an outcome of interest.

This workshop will provide participants with the necessary information to assess the quality of existing instruments. A comprehensive description of psychometric properties will be offered, with special emphasis on the various types of validity and reliability evidence. Subsequently, this information will be used by working groups to discuss and evaluate the quality of different instruments widely used in science education research. Participants will develop a thorough understanding of the aspects involved in the quality of a measurement instrument and will be able to make an informed decision about whether desired instruments have sufficient evidence of validity and reliability to be used with confidence in their research. Participants are not required to have a prior understanding of this topic.

2.5.6 Workshop W6

Friday, September 2, 15:00 – 17:00 CET | Room 061

Science Education Research(ers) and Professional/Disciplinary Identity

Antti Lehtinen
University of Jyväskylä, Finland

Science education concerns itself with at least two different academic disciplines: some field of (natural) science and education. Classically, natural sciences are perceived as “hard disciplines” and education is perceived as a “soft discipline” (Biglan, 1973), but more recently this dichotomy has been challenged (Matthew & Pritchard, 2009). Similarly, science education research most often takes place either in a Department / Faculty of Science or in a Department / Faculty of Education. Many science education researchers will switch from one disciplinary environment to another throughout their career, e.g. from doing their Master’s studies in a Department of Physics to completing their PhD studies in a Department of Education.

Due to these factors, as future science education researchers and science teacher educators (Mork *et al.*, 2021) the summer school participants should actively think about and scrutinize their own professional and disciplinary identities. This workshop centres around questions like: “How do I position myself between (natural) science and education?”, “What is my disciplinary identity like?", and "How has my professional identity been shaped by my experiences and by others around me?"

The workshop includes a brief introduction by Antti as the workshop leader – I outline the necessary concepts (e.g. academic disciplines, disciplinary identity and professional identity) and share my own experience as someone whose academic career has taken him from a Department of Physics to a Department of Teacher Education and then back to a Department of Physics and how that process has shaped my own professional identity. Most of the workshop time will be spent on students' active discussion in small groups working together and discussing and dissecting their own academic paths, experiences, and their professional and disciplinary identities. Active participation by all attendees is necessary. The groups' contributions will be brought to a common discussion in the end of the workshop.

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2.6 Mentor Group Meetings

The Summer School participants have been divided into seven Mentor Groups. Each of these groups consists of seven PhD students and two experienced science education researchers acting as mentors. It is expected that each mentor group will have one or two virtual meetings in the weeks before the start of the Summer School with the aim of clarifying the working method during the Mentor Group Meetings, getting to know each other and acquiring an overview of the research that will be presented and discussed. During each Mentor Group Meeting at the Summer School one of the PhD students will present his/her research to the group in about half an hour, followed by a structured whole group discussion of the strengths and weaknesses of the research presented.

The table below gives an overview of the composition of the Mentor Groups, including the mentors of these groups. All Mentor Group Meetings will be held in the *Buys Ballot building*, Rooms 005, 007, 069, 071, 075, 077 and 079 (Ground Floor), 09:00 – 10:30 & 13:00 – 14.30 CET on Tuesday through Friday.

The (Dutch) names of the Mentor Groups represent some of the typical Dutch 'landscape elements', which will be explained during the Opening Ceremony at the Stayokay Hostel on Monday, August 29.

Some students have (V) behind their name, meaning that it is already clear that they will (have to) participate virtually.

Mentor Group	Students	Mentors	Room
MG 1 Rivieren	Hong Tran (V) Kristina Fricke Caterina Solé Daniel Pimentel Lawrence Houldsworth Eftychia (Evi) Ketsea Franz Schröer	Lukas Rokos May Lee	005
MG 2 Tulpen	Avivit Arvatz Ronja Sowinski Matheus dos Santos Barbosa da Silva Louisa Morris Gozde Tosun Benedikt Gottschlich Kehinde Abdullahi (V)	Martin Rusek Christina Siry	007
MG 3 Windmolens	Jasmin Kilpeläinen Florian Budimaier Kim Blankendaal Carly Busch Sascha Wittchen Kārlis Greitāns Amy Smith	Nicoleta Gaciu Antti Laherto	069
MG 4 Weilanden	Johan Tabora Jos Oldag Isabel Borges Ene Ernst Hoppe Rita Krebs Paola Rigoni Annika Krüger	Giulia Tasquier Antti Lehtinen	071
MG 5 Sloten	Kanella (Nelly) Marosi Anna Lager Axel Langner Ryan Coker Ragnhild Barbu Shannon Stubbs Patricia Kühne	Justin Dillon Regina Soobard	075
MG 6 Grachten	Ye (Catherine) Cao Kate Walker Markus Obczovsky Malte Schweizer Sara Brommesson Lilach Ayali Xenia Schäfer	Reneé Schwartz Veli-Matti Vesterinen	077
MG 7 Duinen	David Weiler Karoliina Vuola Nadia Qureshi Peter Duifhuis Sophie Perry Klaudja Caushi Catharina Pfeiffer	Isabel Martins Radu Bogdan Tomu	079

2.7 Poster Sessions

Each PhD student is also expected to present his/her research by means of a poster. During the Poster Sessions everyone discusses his/her work with all interested Summer School participants. Moreover, everyone will also get written feedback on his/her poster from a science education researcher.

The table below gives an overview of the time schedule of the two Poster Sessions. Both Poster Sessions will be held in the *Buys Ballot building*, Rooms 023 and 083 (Ground Floor), 17:00 – 18:30 CET on Tuesday and Wednesday. A Poster Session is divided into time slots of about 20 minutes. During the first time slot, the students of Mentor Group 1 are expected to stand by their poster while all other students can visit the poster(s) they are interested in. During the second time slot, the students of Mentor Group 2 take over, and so on.

Day	Time Slot	Poster Presenters	Rooms
Tuesday, August 30	17:00 – 17:20	Mentor Group 1	023 & 083
	17:20 – 17:40	Mentor Group 2	
	17.40 – 18:00	Mentor Group 3	
	18:00 – 18:20	Mentor Group 4	
Wednesday, August 31	17:00 – 17:20	Mentor group 5	023 & 0,83
	17:20 – 17:40	Mentor Group 6	
	17:40 – 18:00	Mentor Group 7	

The posters can be put up on the poster boards sometime during Tuesday, and can stay there until Friday. Please note that when putting up the posters, the students of Mentor Group 1 should use the poster boards marked with MG 1, the students of Mentor Group 2 those marked with MG2, and so on. This is to ensure that during each time slot the Poster Presenters – and thus their public – are somewhat evenly distributed over both rooms.

2.8 Virtual Platform

The virtual participants can join the Plenary Lectures, Workshops, Mentor Group Meetings and Closing Ceremony in Teams by using the Virtual Platform (also accessible by means of the QR code on the right). This platform will become operational on August 15, 2022.

The virtual platform can also be used by the other participants to look at (and download) the eBook of Synopses, the digital posters and other lecture-related and/or workshop-related documents that might become available during the Summer School.

3 Synopses

3.1 Mentor Group 1 | Rivieren | 3.1.1

Using Self-Regulated Learning to Optimize Teacher Questioning Skills of Preservice Science Teachers

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Keywords: Teacher Education, Teacher Questioning, Self-regulated Learning, High-cognitive Level Questions

Focus of the Study

Classroom instruction mostly follows a traditional pattern of conversation referred to as initiation-response-evaluation or initiation-response-feedback (Edwards & Westgate, 2005) in which the teacher asks questions with predetermined-answers, elicits a response, and then provides feedback (Benedict-Chambers *et al.*, 2017). Scholars agree that question asking plays an essential role in teaching (e.g., Chin, 2007; Morris & Chi, 2020), but the use of fact-recalling questions is often not helpful for meaningful learning (Benedict-Chambers *et al.*, 2017; Shields & Edwards, 2005). Scholars who study teacher questioning suggest that teacher training is needed to alter classroom discourse patterns (Burns & Myhill, 2004; Townsend & Pace, 2005). Prior research has examined different aspects of teacher questioning (e.g., Lee & Kinzie, 2012; Chen *et al.*, 2017); however, few studies have explored the most effective ways to train teachers on how to ask classroom questions effectively (Morris & Chi, 2020). I attribute this situation to a lack of an effective means of supporting teachers in asking high-cognitive level questions. To develop their teacher questioning skills, teachers need training and need to be supported in learning from their practice. A systematic literature review on self-regulated learning (SRL) training for science teachers (Capps *et al.*, 2021) showed SRL improves both science teachers' learning and teaching, but there is a lack of learning opportunities for teachers that leverage SRL processes to optimize teacher questioning.

Therefore, I propose a new approach to increase the number of high-cognitive level questions preservice science teachers (PSTs) ask during their student teaching. The approach includes training as well as support for PSTs with learning from their practice. In the context of implementing the approach, my dissertation study will help understand (1) how the quality of SRL processes adapted by PSTs in planning and enacting questions might inform the types of questions they ask, and (2) how changes over time in the quality of SRL processes PSTs adapt in planning and enacting of questions might relate to changes in the kinds of classroom questions they ask.

Theoretical Framework

This study is framed by three different theoretical frameworks: the Interactive, Constructive, Active, and Passive (ICAP) framework of cognitive engagement (Chi & Wylie, 2014), Zimmerman's cyclical phases model of SRL (Zimmerman & Moylan, 2009), and Zimmerman's development of self-regulatory skill model (Zimmerman, 2002). Figure 1 summarizes how these three frameworks inform my study.

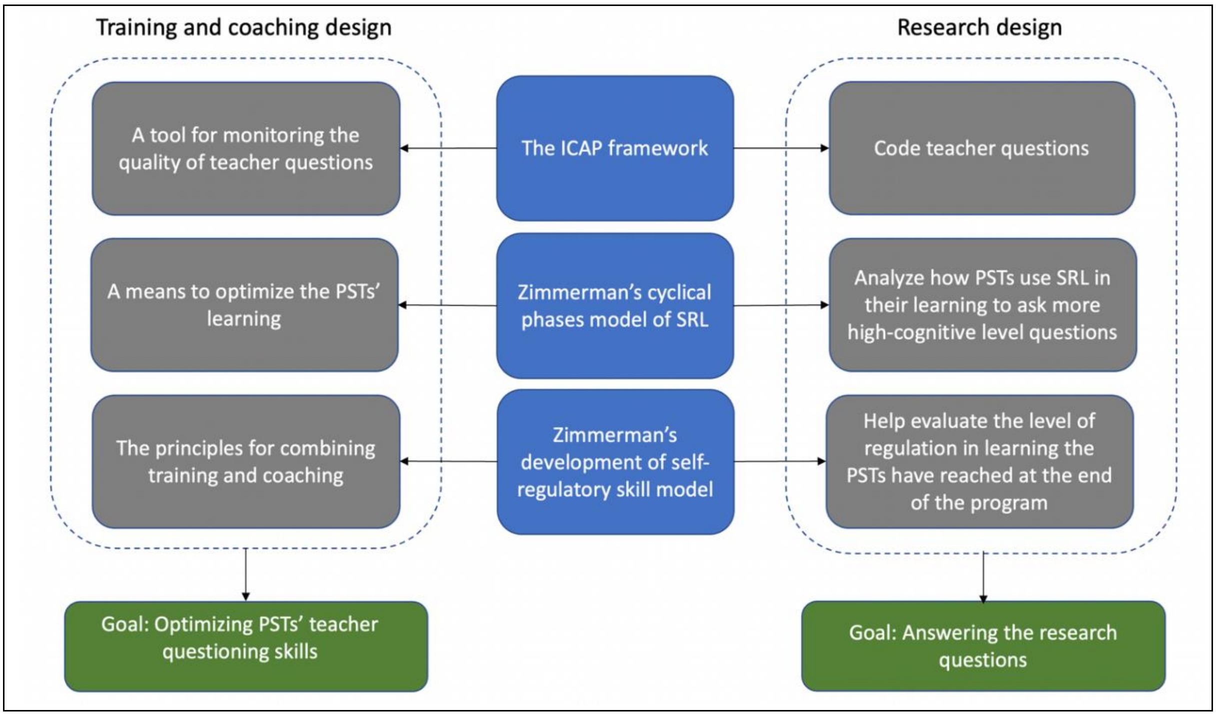

Figure 1. Theoretical frameworks that inform this study.

Research Questions

1a. To what extend do PSTs adapt SRL processes in planning questions for their lessons?
1b. How do PSTs adapt SRL processes in enacting questions during teaching?
1c. How might the quality of SRL processes adapted by PSTs in planning and enacting questions inform the types of questions they ask in the science classroom?
2a. How, if at all, do the quality of SRL processes adapted by PSTs in planning and enacting questions change during student teaching?
2b. How, if at all, do the types of classroom questions PSTs ask change during student teaching?
2c. How might changes in the quality of SRL processes PSTs adapt in planning and enacting questions relate to changes in the kinds of classroom questions they ask?

Research Design and Methods

This research is a descriptive case study. The research method was chosen because it allows investigating in-depth and with real-world context (Yin, 2018).

Table 1. Data sources and timeline for data collection.

Data sources	**Timeline (Spring, 2022)**		
	Jan	**Feb**	**Mar**
Classroom materials (lesson plans, slides, worksheets, etc.)	—	—	—
Semi-structured interview about planning the lesson	—	—	—
Classroom observation	—	—	—
Audio recordings of the teaching	—	—	—
Semi-structured interview about the teaching	—	—	—

Participants

To represent variance among PSTs, three participants were purposefully selected from 18 PSTs enrolled in a certification program for teaching secondary science. The participants represent low, moderate, and high self-regulated learners. A survey, a reflection writing, and my observations while working with PSTs during Fall 2021 helped select the participants.

Data sources

Research data will be collected from multiple sources representing different dimensions of PSTs' SRL and questioning skills. Table 1 shows data sources and the timeline for data collection.

Data analysis

The first set of research questions

Classroom audio recordings will be transcribed using Otter.ai. Once transcribed, the questions will be coded as either passive, active, constructive, or interactive according to a coding scheme that was developed based on the ICAP framework (Chi & Wylie, 2014). After that, the total number of questions asked and the percentage of each type of questions in the lessons will be calculated.

Inductive thematic analysis will be used to analyze the interviews regarding how the PSTs adapt SRL processes in planning and enacting questions (Bowen, 2009). I will conduct two coding cycles: in vivo coding and pattern coding. To make sense of my findings, I might create a cognitive map for each case that displays the participant's SRL processes while planning and implementing teacher questions (Miles *et al.*, 2014).

After identifying the within-case patterns as described above, I will conduct a cross-case analysis. I will compare and contrast the tentative conclusion about within-case patterns to examine whether there appeared to be replicative relationships across the cases and differences among the individual cases (Yin, 2018). In other words, I will examine similarities and differences across cases. I will first look for themes that cut across cases (similarities), and then look at themes that are specific for individual case (differences) (Miles *et al.*, 2014). To facilitate this process, I will create a partially ordered meta-matrix. After that, subsequent analyses will be conducted to draw meaningful cross-case conclusions deeper than the similarities and differences. In other words, I will aim to delineate the deep structures that shared across cases (Miles *et al.*, 2014).

The second set of research questions

I will look at both the products of change and the processes of change. Questions the participants ask in the classroom will serve as the products of change. The processes of change will be evaluated via interviews. Data for this set of research questions are the same as data for the first research question. Thus, teacher question analysis will be done already. I just need to compare the percentage of each type of questions over time. Regarding interviews, I will use themes from inductive thematic analysis as described above to analyze further. The difference compared to data analysis for the first set of research questions is that I will analyze within cases over time. I will create two time-ordered matrices for each case, one for planning, the other for teaching. These matrices will facilitate noting trends that show changes or stability through time (Miles *et al.*, 2014). After analyzing each case, I will create a summary table that brings together all themes from multiple cases into a single form for further analysis (Miles *et al.*, 2014). I will also get back to the transcripts to find quotes illustrating the final findings. Final findings will be written as thematic narratives derived from systematic comparison within cases over time.

Preliminary Findings

I will discuss three key findings of my pilot study reported in three different conference proposals (SASTE, ASTE, AERA; all the proposals have been accepted). First, PSTs stated that the primary goal of asking questions is assessing student knowledge. Accordingly, most of the questions they planned for their lessons aimed to have learners recall information. I argue that to ask questions that go beyond simple recall, PSTs would have needed to understand that assessment was not the only role of teacher questions. Another important role of teacher questions is stimulating student thinking. Second, PSTs did not effectively use the SRL processes while planning their questions. They set unclear goals for planning questions, and the goals were not achieved. The way the PSTs self-monitored their process of planning questions misaligned with their goals. Based on these findings, I argue that fostering PSTs' ability to adapt SRL processes while planning questions has the potential to improve the quality of their questions. Third, PSTs appreciated the role of SRL and had plans to integrate SRL processes into their science lessons. However, they needed more support with implementing SRL in the classroom. This finding suggests the training with PSTs was viewed as valuable. Findings from my pilot study led to designing the approach for my dissertation study that includes training and coaching. The training (including six lessons) has been completed during Fall 2021. Coaching is occurring this Spring.

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Differentiation and Evaluation of the Family Resemblance Approach to Nature of Science

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Keywords: Biology, Expert Interviews, Nature of Science, Secondary Education, Textbooks, Qualitative Analysis

Focus of the Study

Fostering an adequate understanding of the nature of science (NOS) contributes to the development of students' scientific literacy (Lederman & Lederman, 2014), which is reflected in national normative standards (e.g., KMK, 2020; NGSS, 2013). However, studies report that students' understanding of NOS is not fully adequate (Lederman & Lederman, 2014). At the same time, it is reported that NOS representations in school science textbooks are often not fully adequate and mostly in an implicit manner (e.g., Abd-El-Khalick *et al.*, 2008; 2017). Implicit NOS representations still have the potential to address the corresponding content in science class as they can serve as starting points for the development of explicit teaching approaches. They can also be used to illustrate explicit NOS contents on a tangible level (e.g., by introducing case examples). However, studies on the quality of NOS representations in textbooks are often based on discipline-general NOS conceptualizations, which are criticised for being not fully adequate and for disregarding the specificities of scientific disciplines (Schizas *et al.*, 2016). For example, in search of errors in biological experiments the variability of living creatures as research objects must be considered (Bässler, 1991). Such specificities should be addressed in science class (Schizas *et al.*, 2016).

With the Family Resemblance Approach (FRA; Irzik & Nola, 2014) scientific disciplines are described as family members sharing some similarities but differing in certain aspects. By adapting the further developed FRA to NOS in science education research (Erduran & Dagher, 2014), 11 NOS categories are presented in a holistic framework which offers a way to differentiate them corresponding to a scientific discipline. To describe NOS contents of different scientific disciplines more precisely and to derive consequences for the future design of science education materials, the project aims at the differentiation and evaluation of the FRA (Erduran & Dagher, 2014) into discipline-general and biology-specific NOS aspects.

Theoretical Framework

By adapting the FRA (Irzik & Nola, 2014) to NOS, Erduran & Dagher (2014) differentiate 11 NOS categories into the cognitive-epistemic and the social-institutional system of science. The first includes "aims and values", "practices", "methods and methodological rules", and "knowledge"; the social-institutional system of science consists of "scientific ethos", "professional activities", "social certification and dissemination", "social values", "political power structures", "financial systems", and "social organizations and interactions". With the adapted FRA, NOS aspects can be seen as "interactive with porous boundaries" (p. 143), which represents a holistic characterization of science. Several textbook studies confirm the FRA as applicable for the identification of discipline-general (e.g., McDonald, 2017) and discipline-specific, thematically focused NOS contents (e.g., valid only for relativity theory; Park *et al.*, 2019).

Research Questions

For the empirical evaluation and further development of the FRA to NOS, the following research question (RQ) is examined:

1. Which NOS contents can be identified by an analysis of the curriculum for biology education (i.e., biology school textbooks)?

To differentiate NOS contents regarding their specificities for certain scientific disciplines, the research question is as follows:

2. Which of the identified NOS contents can be justified as discipline-general and which of biology-specific by an expert study?

Research Design and Methods

To identify a possibly high range of NOS contents (RQ 1), seven school biology textbooks from different groups of authors and publishers were chosen (Table 1; Abd-El-Khalick *et al.*, 2017). Due to the high amount of data in qualitative textbook research, four chapters (introduction, cell biology, genetics, evolution) were selected in line with studies which report on a high amount of NOS content in these sections (e.g., Abd-El-Khalick *et al.*, 2017).

Table 1. Sample.

Publisher	Textbooks (grades 7-10)	Pages	Textbooks (grades 11-13)	Pages
Wester-mann	Bioskop SI (Bioscope lower level; 2016)	119	LINDER Biologie (LINDER biology; 2019) Biologie heute (Biology today; 2012)	241 211
Cornelsen	Biosphäre (Biosphere; 2016)	104	Biologie Oberstufe (Biology senior level; 2016)	220
Klett	Natura Biologie (Natura biology; 2019)	113	Natura Oberstufe (Natura senior level; 2016)	250

All elements of the textbooks (texts, info boxes, figures, tables, tasks) were considered for the content structuring analysis including a deductive-inductive approach (Mayring, 2015). Based on the 11 categories of the FRA (Erduran & Dagher, 2014), a coding guideline was established. Several training sessions with a second coder, discussions with experts of biology education research (N=10), and coding discussions among the researchers of this project were held until consensus was reached. 15% of the sample were randomly selected and coded independently, which revealed "almost perfect" intrarater-reliability (κ=.95) and "substantial" interrater-reliability (κ=.80; Landis & Koch, 1977, p. 165). Subsequently, the first author coded the rest of the material.

For differentiating discipline-general and discipline-specific NOS aspects (RQ 2), an expert study (N=33) will be conducted. For this, professors and post-doc level researchers of biology, chemistry, physics, and science philosophy are currently requested to participate (Kaiser, 2014). According to the textbook chapters (study 1), experts of biology are selected from the disciplines of cell biology, genetics, and evolution. Considering a broad coverage of disciplines, physicists from the fields of thermodynamics, electrical science, optics, and nuclear physics (Abd-El-Khalick *et al.*, 2008; 2017), and chemists from the fields of inorganic chemistry, organic chemistry, and theoretical chemistry are consulted.

Based on the results of the first study (Table 2) a structured interview guideline is currently developed and will be pretested. After presenting single subcategories including descriptions to the experts, they will be asked to justify if and/or how the content of each subcategory matters in their scientific discipline and to give rationales, e.g., case examples. Discrepancies between the findings are passed back to the experts within the setting of a communicative validation process (Bryman, 2016).

Preliminary Findings

The FRA to NOS (Erduran & Dagher, 2014) was modified (e.g., by splitting "methods" and "methodological rules") and differentiated into 29 subcategories for the cognitive-epistemic and 23 subcategories for the social-institutional system of science (Table 2; Reinisch & Fricke, 2022).

Table 2. (Sub-)Categories of the cognitive-epistemic system.

Categories	Subcategories (numeration in lowercase letters)
(1) Cognitive-epistemic Aims and Values	(a) Objectivity, (b) Testability, (c) Novelty, (d) Criticism, (e) Empirical Adequacy
(2) Scientific Practices	• Empirical practices: (a) Observing, (b) Experimenting, (c) Comparing and Classifying, (d) Modeling • Work techniques: (e) Chemical and Physical Analysis, (f) Mathematics, (g) Preparation • Documentation: (h) Protocolling, (i) Drawing, (j) Taking Photographs, (k) Constructing Diagrams
(3) Methods	• Scientific Approaches: (a) Hypothetic-deductive Approach • Forms of Reasoning: (b) Inductive Reasoning, (b) Deductive Reasoning, (c) Abductive Reasoning
(4) Methodological Rules	(a) Rejection or Change of Inconsistent Concepts, (b) Conduction of Controls, (c) Choice of Sample Size, (d) Choice of Research Object, (e) Avoidance of Ad-hoc Changes in Theoretical Constructs
(5) Knowledge	(a) Hypotheses, (b) Theories, (c) Models, (d) Laws
(6) Professional Activities	(a) Publishing Findings, (b) Evaluating Research Quality, (c) Undertaking Research Trips, (d) Receiving Awards and Prizes
(7) Scientific Ethos	(a) Respect of Research Objects, (b) Respect for the Environment, (c) Protection of Human Subjects, (d) Confidentiality, (e) Communalism, (f) Legality
(8) Social Utility	(a) Improving Human Health, (b) Supporting Nature Conservation, (c) Serving Justice
(9) Social Organization and Interactions	(a) Teamwork, (b) Social Organization of Institutions
(10) Power Structures	(a) Scientific Community, (b) Science and Policy, (c) Science and Religion, (d) Science and Society, (e) Interplay of Science with 'Race'
(11) Economics of Science	(a) Application and Transmission, (b) Commodification and Commercialization, (c) Financial Support

A high number of overlaps (e.g., between (2)"Scientific practices" and (3)"Methods") has been identified. Overlaps do not necessarily hint to missing discriminatory power but can show the categories as being "interactive with porous boundaries" (p. 143), which is an advantage of the FRA for its use in the classroom: The FRA depicts "science as a holistic, dynamic, interactive and comprehensive system" (Erduran & Dagher, 2014, p. 29). Hence, the discriminatory power of the subcategories must be discussed along further analyses.

Currently, we are planning and preparing the second study. In line with the literature, both discipline-general and biology-specific NOS categories can be assumed (Schizas *et al.*, 2016):

- discipline-general NOS aspects: the whole subcategory content relates to all or most disciplines of the natural sciences (e.g., (1a)"Objectivity", Table 1; Resnik, 2007),

- discipline-general NOS aspects with inherent specifications for biology: the subcategory content partly relates to biology (e.g., (2b)"Experimenting", Table 1; Bässler, 1991),
- biology-specific NOS aspects: the whole subcategory content relates only to biology or very close-related subdisciplines, e.g., (7a)"Respect for Research Objects", Table 1; Resnik, 2007)

By means of the expert study, results are expected to lead to a classification of the differentiated FRA categories (Table 2).

Implications for science education research are derived regarding the development of NOS teaching approaches by a more appropriate addressing of biology-specific NOS aspects. Also, an evaluation of the differentiated FRA is assumed to foster the examination of both NOS contents of further disciplines (e.g., specificities of chemistry) and corresponding NOS representations (e.g., extent and quality of NOS representations in chemistry and physics textbooks).

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3.1 Mentor Group 1 | Rivieren | 3.1.3

Citizen Science in Schools: Contributions to Students' Ideas of and about Science from an Air Pollution Project

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Keywords: Science, Secondary Education, Citizen Science, Air Pollution, Scientific Practices, Epistemic Practices

Focus of the Study

Both for democratic reasons and to accelerate science, citizen science initiatives have gained popularity in the last years. The term 'citizen science' refers to "the general public engagement in scientific research activities when citizens actively contribute to science" (Socientize Consortium, 2013). This type of initiatives have also entered the classrooms. However, how this initiatives could contribute to students' scientific literacy is a topic scarcely researched. Thus, in this doctoral thesis we explore the phenomena of citizen science in schools with the aim of contributing a theoretical and empirically based conceptualisation of a form of citizen science that truly serves both scientific and educational purposes. In our framework, we called this new version school-based citizen science.

Firstly, in order to establish a tentative framework for school-based citizen science, we propose a systematic review about existing citizen science projects which are implemented in classrooms, how these projects are designed, implemented and evaluated in practice and what sort of outcomes, including school science learning outcomes, are reported by these projects in the existing literature.

On the other hand, under our perspective, citizen science which expects to have a rich pedagogic dimension and become part of the students' curriculum, should take into account that students have to be involved in scientific practices (Osborne, 2014), but also in epistemic practices (Jiménez-Aleixandre & Crujeiras, 2017), developing ideas of and about science.

To explore these issues, we iteratively co-develop and carry out the educational part of a citizen science project about air pollution which were conducted in secondary schools in [To be inserted later] during two academic years. In addition to its curricular interest (connected with the particulate model of matter), the topic was chosen because air pollution is one of the most relevant environmental issues in cities (WHO, 2021).

In this context, and from a model and modelling-based perspective (Couso & Garrido-Espeja, 2017), we have explored how secondary students understand air pollution before and after participating in a Teaching and Learning Sequence (TLS) integrated in the citizen science project. Finally, related with the epistemic goals and ideas about science, one of the current challenges is the students' trust in science (Cobern, Aj, Brandy, Andrew, & Kagumba, 2022), and specially, within these new paradigms where citizens participate directly. As such, we propose to explore how students trust professional scientific research in comparison with how they trust citizen science research in which they participated, analysing students' epistemic values and performances in school-based citizen science.

Theoretical Framework

Connecting citizen science initiatives with school contexts would appear to be a fruitful relationship (Harlin, Kloetzer, Patton, & Leonhard, 2018). From an educational perspective, these initiatives have to be coherent with the main consensus about how students learn science and what they have to learn about science. Related with how, a crucial perspective due to its epistemic relevance is the engagement of students in scientific practices (Osborne, 2014). Related with what, we agree that in mandatory school context we should address big ideas of science (Harlen, 2010), but also ideas related with the nature of science explicitly (Duschl & Grandy, 2012).

One of the most important models of science is the particulate model of matter (Harrison & Treagust, 2002) which is vastly researched (Hadenfeldt, Liu, & Neumann, 2014). This model is crucial to explain air pollution caused by particulate matter, but due to the mesoscopic scale (Meijer, Bulte, & Pilot, 2013) of particulate matter, this context implies new challenges to its teaching and learning (Tena & Couso, 2021).

On the other hand, related with the nature of science and epistemic practices (Kelly & Licona, 2018), one of the objectives of epistemic education is that students succeed in epistemic activities such as forming judgments (Barzilai & Chinn, 2017) or reasoning about the trustworthiness of science. Research about the complex relationship between knowledge and values (Kolstø, 2006; Tytler, Duggan, & Gott, 2001) is needed.

Research Questions

To explore the phenomena of citizen science in schools, our research questions are:

1. Which elements characterise the citizen science projects that are implemented in classrooms?
2. What model of air pollution do students have before and after participating in a TLS integrated in a citizen science project?
3. How students trust in citizen science research in which they have participated in comparison to professional scientific research?

Research Design and Methods

This research has a qualitative approach because it tries to delve into the understanding of a phenomenon in its context, analysing meanings and ideas (Neuman, 2014).

The first question is addressed through a systematic review under PRISMA protocol (Page *et al.*, 2021) of the international literature integrating content analysis. In the identification phase we are using Web of Science database with an initial n = 101. The phases of screening and deciding the inclusion and exclusion criteria are being developed.

In order to answer the second and the third question we use the context of a citizen science project about air pollution leaded by a well-known scientific research centre. In which, 14-15-years-old students from more than 30 high schools were engaged during the 18-19 and 19-20 academic years.

Specifically, to answer the second question we collected pre and post data from the individual productions of the students asked to draw and describe in written form how was the air of an hypothetical sample of polluted air. These multimodal representations were analysed with a coding system created using inductive-deductive methods in terms of two dimensions: ideas regarding the nature of polluted air and ideas regarding the structure. Due to the lockdown caused by COVID-19 pandemic, only 205 students from 4 high schools were able to complete all the activities of the designed TLS and conform our convenience sample.

Finally, to answer the third question, we collected data from the individual written responses of students about how much and why they trust the results of a scientific research presented in press, and how much and why they trust the results of the citizen science experiment in which they participated. In this part of the research participated 9 high schools with 276 14-15-years-old students. In order to analyse these answers, we are developing a framework based on Couso & Puig (2021) and Lee (2012) which tries to unravel from which stance students trust, or not, scientific research (i.e. affective, values and epistemic) and which are the main reasons to do it.

Preliminary Findings

At this stage of the thesis we have finished and presented in an international conference results related with question 2. As an example, we include here in Figure 1 initial representation in which almost a half of the students show polluted air as a unique substance in a semicontinuous form in the mesoscale. The same analysis has been done with students' final representations for comparative purposes, but they are not included here due to space limitations.

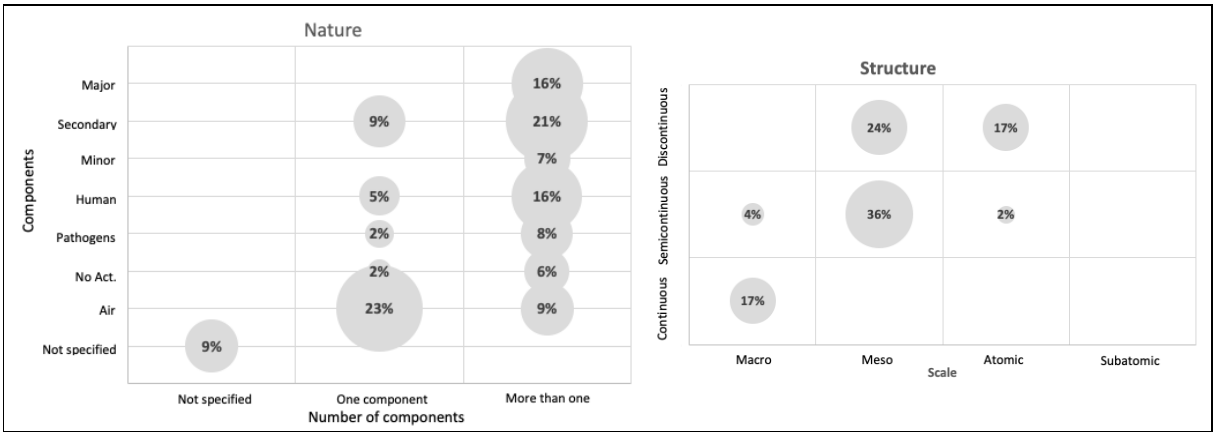

Figure 1. Initial representations of students' ideas of polluted air in terms of nature and structure.

Regarding questions 1 and 3, which are being developed at the moment, we aim to have preliminary results by the time of the ESERA Summer School.

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3.1 Mentor Group 1 | Rivieren | 3.1.4

Learning to Evaluate Scientific Evidence in the Age of Digital Information

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Keywords: Science, Secondary Education, Nature of Science, Credibility

Focus of the Study

In an increasingly digital world, young people turn to the internet for information about COVID variants, climate change, and a range of scientific and socio-scientific issues. One challenge with relying on the internet as a primary source of scientific information is that much of the information found online is unvetted and lacks credibility checking (Chinn *et al.*, 2021). As a result, misinformation spreads easily over the internet (Vosoughi *et al.*, 2018). The challenge of misinformation is particularly relevant to science and science education because to evaluate the credibility of scientific information, individuals should develop an understanding of the social processes of science, such as peer review and consideration of scientific consensus and prior findings (Höttecke & Allchin, 2020; Oreskes, 2019).

The purpose of this study is to explore how lesson materials might help high school students learn about the social processes of science, such as peer review and consensus, and support their evaluation of scientific information online. The lessons in this study draw from the nature of science-in-society (Höttecke & Allchin, 2020) and civic online reasoning (Wineburg *et al.*, 2022). I selected the first framework due to its emphasis on understanding the social processes of science in relation to broader society and the second framework due to its demonstrated success in supporting high school students with evaluating information online (McGrew, 2020).

I am conducting this study in collaboration with a ninth-grade biology teacher and her students in California. In the United States, students are not systematically taught about topics such as scientific expertise, credibility, and consensus nor are they taught to use these ideas to evaluate scientific evidence online. This exploratory study will prototype curriculum materials and describe how these materials impact students' evaluations of online information, if at all. In doing so, this study contributes much needed knowledge about how educators can support science media education in secondary schools (Reid & Norris, 2016).

Theoretical Background

The nature of science-in-society (NOSIS) is a framework that includes traditional nature of science topics (e.g. empiricism, tentativeness, and alternative explanations), but it also emphasizes social processes of science that allow for the production of reliable knowledge, such as peer review, expertise, consensus, and science communication. (Höttecke & Allchin, 2020). These factors have traditionally received less emphasis in nature of science frameworks (Dagher & Erduran, 2016). NOSIS is relevant to this study because it includes an emphasis on the epistemic issues that arise when scientific information moves from the scientific community into the public via media. The public's understanding of science is "situated firmly in the widespread goals of scientific literacy in general and NOS education in particular" (Höttecke &

Allchin, 2020, p. 643). Therefore, NOSIS situates issues of science in the media, including misinformation, as important issues for science education.

One approach to address science misinformation is by teaching students to "critically evaluate evidence and explanations, take into account the source of that information, and appreciate how the methods of science lead to specific conclusions" (Sinatra & Hofer, 2021, p. 4). Such an approach requires a shift in how students are taught to engage with evidence in the science classroom. Although many curricula do place an emphasis on engaging students with scientific evidence, little guidance is provided for engaging students in "the broad and complex nature of evidentiary reasoning" that students will need to use in their everyday lives (Duncan *et al.*, 2018, p. 909). Engaging students in evidentiary reasoning for everyday life would involve teaching them epistemic criteria for evaluating scientific evidence, such as *source trustworthiness*, *validation by knowledgeable others*, and *acceptance of claims in the scientific community*. Importantly, students would also need to learn processes for evaluating these criteria, such as identifying relevance and level of expertise, sources of bias, levels of scientific consensus, and peer review status (Duncan *et al.*, 2018).

Teaching students to evaluate scientific evidence in the context of the science inquiry activities does not guarantee that students will apply these ideas online. Navigating information on the internet is fundamentally different due to the interconnected nature of the information presented online (Wineburg et al, 2022). As a result, students should be taught the knowledge and practices necessary to use the interconnected nature of the internet to their advantage. Civic Online Reasoning (COR) is a framework within the field of media literacy education, and it focuses specifically on teaching students to evaluate online information (Wineburg et al, 2022). As a part of the framework, students learn when and how to apply heuristic strategies such as *lateral reading*, opening new tabs to search for information, and *click restraint*, which involves practicing patience when clicking on new links. COR focuses on helping students answer three questions about information sources such as "Who is behind this information?", "What is the evidence?", and "What do other sources say?".

Civic online reasoning is a conceptual framework that focuses on navigating information in a domain-general fashion. I propose that for students to develop *scientific online reasoning*, they must develop *both* an understanding of the epistemic understandings and strategies for navigating and evaluating digital information as outlined in COR *and* the epistemic understandings and strategies for evaluating scientific evidence as outlined above.

Research Questions

This exploratory project has three primary questions:

1. How do high school students describe expertise in science, peer review, and scientific consensus before and after a curriculum unit prototype?
2. What learning activities promote students' use of scientific online reasoning?
3. What changes do we observe in students' use of scientific online reasoning throughout a curriculum unit prototype?

Research Design and Methods

This qualitative, exploratory study has two primary purposes. One goal is to design and prototype curriculum materials that teach students to engaging in scientific online reasoning, building on frameworks such as NOSIS and COR. A second goal is to describe how students' use of scientific online reasoning changes, if at all, throughout a learning experience using these materials. To those ends, this study has the potential to contribute both practical tools and new insights into how students learn to evaluate the credibility of scientific information on the internet.

Context & Participants

I will work with one high school biology educator in California and two sections of their biology classes. I have chosen to work with a biology class because the topics that are taught in this class relate to various socio-scientific issues (e.g. climate change) that are relevant to students and the evaluation of credibility.

Methods

The curriculum materials are under development and focus on topics such as peer review, consensus, expertise, and online reasoning strategies. The full sequence will include materials for 15 lessons lasting 50 minutes each. They will be taught over the spring semester. I will collect interviews from the teacher and the students, along with classroom videos, student work samples from select timepoints during unit, and observation field notes. I will analyze the data using a combination of deductive and inductive codes drawing from my theoretical framework and themes that emerge in the data. Table 1 illustrates how the data will support answering of the research questions.

Table 1. Alignment between research questions, data sources, and analysis.

Research Question	Participants	Data Sources	Data Analysis
RQ1	Students (14-15 years old)	Interviews	Content & Thematic Analysis using deductive & inductive techniques
RQ2	Educator Students (14-15 years old)	Interviews Field Notes Classroom Video	
RQ3	Students (14-15 years old)	Classroom Video Student Work	

Preliminary Findings

Preliminary findings are not available for this proposal; data collection for this project is scheduled to begin in early spring 2022. I will analyze the data by constructing a deductive codebook (Boyatzis, 1998) using constructs from the *a priori* frameworks outlined above. Based on analysis of the data, inductive codes may be added to the codebook if they support answering the research questions outlined above. I will engage in a qualitative thematic analysis to answer the three primary research questions.

The expected preliminary analyses should reveal that a) students' ideas about expertise, peer review, and consensus become more refined after participation in the prototype, b) learning activities that engage students in authentic use of the open internet promote use of scientific online reasoning, and c) that students begin to use epistemic criteria to evaluate scientific evidence online after participating in the learning experience.

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3.1 Mentor Group 1 | Rivieren | 3.1.5

Supporting Teachers to Foster More Gender-sensitive Science and Mathematics through Video-based Professional Learning

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Keywords: Science, Mathematics, Secondary Education, Gender, Teacher Growth, Professional Learning

Focus of the Study

Girls are consistently under-represented in the advanced study of science and mathematics in England (Mcdool & Morris, 2020). In 2019, only 39% of maths and 23% of physics A-Levels were awarded to girls (Department for Education, 2019). Evidence on how classrooms can both recreate and challenge dominant gender discourses around science and mathematics has steadily grown. The idea of gender-sensitive classrooms has emerged but remains nascent, with particular questions around how to support teachers to move towards more gender-sensitive practice. This study explores how video-based professional learning can be used to this end.

Review of Literature

In the pursuit of understanding and addressing gender inequity in science and mathematics, gender studies in education have in recent decades come to increasingly focus on the gendered nature of the classroom. Quantitative studies have helped to challenge entrenched arguments of biological determinism and essential differences (Hyde & Mertz, 2009; OECD, 2019) whilst extensive qualitative research into gender discourses has documented the gendered nature of mathematics and science (Archer *et al.*, 2017; Mendick, 2006). These have been coupled with efforts to concentrate on the unanswered questions around gender inequity following the so-called 'Boys Turn' in policy and media circles at the turn century (Skelton and Francis, 2012). Together these have all helped to concentrate attention on how classrooms can be spaces that both recreate gender norms and stereotypes and that transform these (Lidar *et al.*, 2020).

From this the idea of gender-sensitive classrooms has emerged as potentially transformative spaces. Gender-sensitive classrooms are grounded in post-structural theory and take a theoretical stance against both the neutrality and so-called 'blindness' of first wave feminism and the essentialising of gender that characterised second wave feminism (Forde, 2013). A growing body of research has also worked to better understand what gender-sensitive classrooms may look like in practice, such as through the organisation of classroom activities (Lidar *et al.*, 2020) and the presentation of mathematics and science to challenge dominant heteronormative discourses (Bianchini *et al.*, 2003). Another key area has been pedagogical practices, such as the need to be sensitive to the extensive research on how teachers' feedback and expectations can be highly gendered (Myhill and Jones, 2006) sometimes even unconsciously (Consuegra *et al.*, 2016).

This raises the question of how teachers can be supported to foster more gender-sensitive classrooms. Teacher professional learning has changed dramatically in recent decades, with a notable shift away from a 'deficit perspective' towards more teacher-centred, collaborative professional learning that is more closely tied to teachers' direct experiences and practice (Desimone, 2009). The idea of teacher growth resonates with this shift and the core idea that learning to teach is ongoing, as argued by Clarke and Hollingsworth (2002) whose Interconnected Model of Professional Growth (IMPG) theorises teacher growth as a complex and dynamic process that does not happen uniformly. However, understanding around how teachers grow when trying to move towards more gender-sensitive practice remains limited, with a notable need for more empirical examples (Andersson, 2012). One particularly promising avenue in this respect is the adoption of video-based professional learning. Video provides a concrete and authentic representations of professional practice and a common resource for collaboration to occur around (van Es, 2012). This study seeks to explore how video-based professional learning can be used to support teachers to foster more gender-sensitive classrooms.

Research Questions

The study aims to answer the following research question: *How can video-based professional learning foster more gender-sensitive classrooms?*

The study approaches this question through empirical fieldwork by designing and implementing a video-based professional learning intervention with teachers and then examining this intervention from two different standpoints in order to answer the proposed research question. The first standpoint relates to teachers and, drawing upon the IMPG, how the video-based professional learning affects them: *How does teacher growth manifest in terms of teachers' personal domain, domain of practice, and perceived outcomes?* The second standpoint considers students: *In what ways do students experience these more gender-sensitive classrooms?*

Research Design and Methods

The mathematics and science departments of three English state-funded schools will take part individually in a professional learning intervention. The intervention consists of four monthly workshops which invite teachers to collectively consider gender inequity in science and mathematics and how to foster gender-sensitive classrooms in their particular context. In particular, three of teachers' lessons with a class of 12-13 year olds are filmed, with excerpts of these then shared and discussed in workshops.

This is a mixed methods study using a pre-post design. Prior to and following the intervention, teachers and students complete the What is Happening in this Classroom? (WIHIC) questionnaire, which has underpinned research on classroom learning environments (Skordi and Fraser, 2019). The instrument's seven domains overlap nicely with the literature of gender-sensitive practice, such as examining student cohesiveness, teacher support, and student involvement. Alongside the questionnaire, there is also a semi-structured interview with teachers and a focus-group interview with a sub-sample of students at both time points.

To further capture the process of growth, the study also makes use of measures during the intervention. Participating teachers take part in two video-stimulated recall interviews. These offer a window onto teachers' 'in-the-moment' thinking in the classroom, which research has found to be potentially gendered and sometimes unconsciously (Consuegra *et al.*, 2016). Each workshop is also recorded and transcribed.

Quantitative data analysis of the WIHIC data will consist of a repeated measures analysis of variance at the school- and sample-level. An analysis of variance of teachers' and students' responses will also be carried out at both time points to assess any particular changes in terms of the differences between their perceptions.

Qualitative data analysis will hinge upon Clarke and Hollingsworth's aforementioned conceptual framework (2002). Interviews and workshops will be transcribed and then thematically analysed in NVivo using the domains of the IMPG. A secondary analysis will then be conducted within these three domains, this time informed by the seven dimensions of the WIHIC to try to identify in greater detail how teachers foster more gender-sensitive classrooms.

Preliminary Findings

The study is currently finalising recruitment of the three participating schools who will complete the professional learning intervention between April and July 2022. Data collection will have been completed and the data cleaned and analysed by the end of July, resulting in a wealth of data for discussion at the ESERA summer school.

A pilot study was completed in July 2021 with one mathematics teacher in England. This saw the trialling of the teacher-level measures, including semi-structured and video-stimulated recall interviews, and the student-level questionnaire. The pilot study demonstrated the value of adopting both a teacher and a student perspective. Hence, as Table 1 demonstrates, the majority of students reported an environment of collegiality, which echoed the perceptions of their teacher. However, there was also a degree of discrepancy insofar as students' perception of the degree of teacher support varied, with a third of students reporting that the teacher only 'sometimes' or 'seldom' took a personal interest in them.

Table 1. Average item mean and standard deviation for student-level WIHIC.

	Average Item Mean	Average Item SD
Student Cohesion	4.17	0.78
Teacher Support	4.03	0.93
Student Involvement	3.96	0.88
Investigation	3.61	0.84
Task Orientation	4.31	0.79
Co-operation	4.00	0.99
Equity	4.50	0.82

The pilot study also shed rich light on the tension between classrooms recreating gender norms and classrooms being a transformative space. For instance, the discourse that mathematics depends on natural flair surfaced (Mendick, 2006), with the teacher noting how some students did not have "the speed of our best mathematicians". At the same time, the teacher discussed how girls can "back away" from mathematics and that it was therefore important to ensure girls had "an equal amount of time, air time…[and] an equal voice in the class". In this respect, the pilot study flagged the potential of the study to shed light on gender discourses in the classroom and the potential value of examining these through a model of teacher growth.

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3.1 Mentor Group 1 | Rivieren | 3.1.6

Secondary Students Drawing Comics for Physics Learning

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Keywords: Physics, Secondary Education, Comics, Drawing

Focus of the Study

The objective of this study is to explore the potential benefits of students drawing comics on the learning of physics in the context of the secondary classroom.

A widely accepted definition of comics is "juxtaposed pictorial and other (including letters and words) images in deliberate sequence" (McCloud, 1993, p.9). Moreover, comics are considered as using a visual language that has its own lexicon (comprising items of various morphologies), grammar, and including a narrative, a navigational and a conceptual structure (Cohn, 2013). As such, the language of comics lends itself to the hypothesis that it can be utilised in teaching and learning and especially in physics. The "cohabitation of words and pictures in a sequential-simultaneous ecosystem" (Sousanis, 2015, p. 64), appears to be particularly conducive for the cognitive manipulation of numerous physics concepts such as changes in the points of view (and reference systems or standards), changes in scale/scope of different interactions, the formalism/symbolism as for example force vectors, field lines and diagrammatic representations, to name some examples.

For example, in the case of causal reasoning and simultaneity (often related to students misconceptions in physics), previous research (Viennot, 2007) has shown that when students formulate explanations in a narrative form, they often adopt a common reasoning characterised by linear simplification, presenting a chain of transformations related to only one of the variables involved (with an underlying chronology which turns the explanation into "a story"). In this case, the comics format can deliver more sophisticated possibilities (e.g., representing causality for one variable and simultaneity for others) because although comics are read sequentially like text, the entire composition is also viewed all at once as a connected space, a web of elements forming a cohesive whole, where there is a spatial interplay of the sequential and the simultaneous (Sousanis, 2015).

Review of Literature

Research on the (various ways of the) use of comics in the classroom started in the 90s (parallel to certain acclaimed publications on the subject of comics itself - e.g., McCloud, 1993 - that contributed to raising its previously lower status of a popular art form of poor value). In general, these research studies review and analyse published comics aiming at communicating science to the public (including school students), identify their advantages and constrains (Tatalovic, 2009) or focus on the science popularisation characteristics adopted (Baudry & Crepin, 2019; Farinella, 2018).

One of the ways to use comics in the classroom is the creation of comics by the students. Here, the scope of research is more limited and the part focusing on secondary science education even more so. Gonzales-Espada (2003) presents a teaching strategy of having students draw "a scientifically accurate comic strip" in a physics class. In Lo Iacono et al (2011), comics by students in a biology class aimed at raising student's awareness on Nature-of-Science concepts and the process of peer-review. In a study by Albrecht et al (2012), students drew comics after a period of physics teaching for learning outcomes evaluation. The one clear general result in all the above studies was that those activities increased student motivation. Finally, in a research project by de Hosson et al (2019), teenagers created comic pages on science and maths topics priorly presented by a scientist and the comics produced were analysed in terms of the relation between the science content and the choices of the comics' narrative and graphical characteristics/elements employed.

Although it has been widely claimed that drawing comics can enhance learning by promoting multi-modal thinking, ideas generation, dealing with ambiguity and making connections (Carlson et al, 2020; Sousanis, 2015), these questions have not been addressed in research. Also, more specifically, the links between the activity and the actual students' learning (outcomes or processes) rest unexplored.

Research Questions

1. What aspects of the students learning in physics are enhanced due to their drawing comics?
2. What are the characteristics of the comics creation activity that enhance each aspect of learning and what are the processes through which this is achieved?

Theoretical Framework

We are planning to use three theoretical frameworks. Firstly, the TAD theory (Chevallard, 2013) will be used for both the design and the analysis in this research on a macro to a meso level comprising all the components that make up the researched instance of physics education ("didactique de la physique"): institutions, actors, actions, tasks, skills, knowledge, and theories. Through the structure provided by this theory, we will look at:

- The effects on learning due to the functioning of the system ("system didactique") consisting of all the above-mentioned components.
- The "praxeologies" ("packets" of tasks, skills and the -science education- reasoning that justifies and relates them to a specific physics knowledge) employed and their effect on learning.

In a second, meso-micro level, this study will look closer at the learning processes at play during the comics creation by employing the theoretical framework of the "instrumental genesis" of Rabardel (1995). In this case, the comics can be viewed as a "psychological instrument" (as do language, symbols, and diagrams according to the Vygotskian tradition) and also as a "semiotic instrument" (Rabardel, 1995) with its own visual language. This theory views "an instrument" as including an artifact/object component (in our case: the comics pages) and a "utilisation scheme" component comprising the actions taken during its use (creation/development). In our case, these actions correspond(/reflect) to the learning processes.

In a third micro level, we will link the comics creation outcomes/processes to the learning/cognition ones using semiotic theory. This theory views both learning and cognition as a semiosis i.e., the processes through which significations emerge, transform, evolve, and disappear (Cunningham, 1998). Analysis of the signs (and their evolution during the creation process) in the comics will provide a mapping to the learning and cognition processes at play. Shank's classification of signs (Cunningham, 1998) adapting Peirce's classifications in an educational context will be a valuable tool here.

Research Design and Methods

The crossdisciplinarity in this project lends itself to a Design-Based Research (DBR) methodology as it is "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (Wang & Hannafin, 2005, p.6).

In this methodological context we will first design a lesson sequence comprising science lessons (on a physics topic) and arts lessons (on drawing/comics creation) and involving both a science and an arts teacher. Two important points here are (a) the exploration of the ways the comics language can contribute to the achievement of the priorly specified physics learning objectives and (b) exploration of the best arts/comics teaching practices to maximise the scope of the comics instrumental potential by the students.

The second phase will be the implementation of the lesson sequence and data collection. We are working with several classes of the level of the 4th and/or 3rd "classe" (grade) of the French "collège" (ages around 13-14 yrs) in one school. Data will include primarily the produced comics but also photographs of them as they evolve. Additionally, there will be video/audio recordings of parts of the lessons, and the a-priori and a-posteriori capturing of students conceptions and knowledge.

Qualitative data processing will provide the answers to the research questions by analysis including:

- Identification of the "praxeologies" (Chevallard, 2013) packets made possible by the activity of comics creation.
- Identification of the "utilisation schemes" (Rabardel, 1995) employed by the students mapping the learning processes along the shaping of the final state of the comics instrument.
- Semiotic analysis of the finished and evolving comics identifying the dimensions/characteristics of the learning processes (types of reasoning, concepts representation and processing, skills, problem-solving strategies, interactions between representation choices, metacognition, etc.) and their evolution/development, based on the signs and the semiotic characteristics found in the comics and the visual language employed.

Preliminary Findings

With the delays of the present COVID situation, we are currently at the phase of the collaborative design of the lesson sequence. Data collection is planned to start in February 2022 with possible iteration before the end of the current school year when we expect to have preliminary findings.

It is also noted here that the author of this proposal has applied the type of data processing of comics pages described above, in a limited way, in the similar context of university education (in the framework of a master's degree dissertation focused on the constraints of the comics creation activity as it was taught to a group of PhD students which then undertook it with the aim of communicating science content).

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Technology as a Topic in Inclusive Primary Education Considering Students' Needs towards Technological Learning in Primary Schools

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Keywords: Technology Education, Inclusion, Primary Education, Basic Needs, Grounded Theory

Focus of the Study

Research on technological education in interdisciplinary science and social studies (Sachunterricht) in German primary schools emphasizes that children are interested in technology (Möller, 2018). While several STEAM initiatives point towards a growing recognition of technological literacy, the consideration of technology education in interdisciplinary science and social studies is quite underrepresented in practice as well as in research and teacher training (Wensierski & Sigeneger, 2015). Taking into account the UN-CRPD claims for an inclusive educational system and thus the right to equally participate in a free society (United Nations (UN), 2006), participation in society through participation in technological development is a fundamental common goal of technological and inclusive education and part of widely recognized technological literacy. It is therefore not well understood how teaching and learning arrangements can consider and satisfy the needs of *all* different students.

The research project presented therefore tries to unveil the appearance of student's basic needs in relation to technological education for all children. In addition, the field study aims to clarify on strategies in service teachers use to consider students' needs whilst planning and designing teaching and learning arrangements.

An initial part of the grounded theory study already examined the subjective significance of basic psychological needs in interdisciplinary science studies among students, to allow for a well-reasoned sample choice for subsequent interviews. The preliminary quantitative results point towards several implications on the diversity of students´ needs in science and social studies.

Theoretical Framework

Student's behaviour in a primary school class just like every human action aims towards the optimal functioning in their environment. This according to Nuttin (1984) so called individuum-environment-relationship is among other things characterized by the individuum's needs. A person's individual needs can therefore be described as functional requirements or necessities of the individual, directed towards its environment (Nuttin, 1984). It is widely common sense that the psychological needs of a person other than physiological needs (e.g. hunger, thirst, sleep) tend to intensify when satisfied by conditions of the environment (Krapp, 2005). This implicates on a theoretical basis, that the circumstances for need satisfaction or frustration one is or has been dealing with determine, how subjectively salient or centrally represented these needs are in his individual goals or lifestyles (Ryan & Deci, 2018). Besides several other theoretical frameworks, the basic psychological needs theory is by far the most cited in educational research contexts. Considerable efforts have been made in recent years to validate its fundamental differentiation of basic psychological needs into the need for (1) *autonomy*, (2) *competence* and (3) *social relatedness*.

Empirical findings on the design of technology education in primary schools indicate that especially practical and problem-solving activities can support personal development in general and particularly the self-efficacy in hands-on learning activities that satisfy the basic psychological needs for autonomy and competence among them (Beinbrech, 2003, p. 214; Tenberge, 2002, p. 186f.)

However, whilst several studies reveal that the satisfaction of basic psychological needs in general has a positive effect on learning outcomes and intrinsic motivation (Niemiec & Ryan, 2009; Krapp, 2005) barely any research specifies the individual variations in students' needs and among the needs of diverse students in primary education (Zhou *et al.*, 2019). Taking into account the UN-CRPD's claim for an inclusive educational system on all levels and therefore the necessity of inclusive classes and learning environments considering the diverse needs and potentials of all students the following questions remain open.

Research Questions

Due to the review of literature these research questions can be derived:

1. How can the needs of primary school students in the context of the broad content of interdisciplinary science and social studies be described?
2. How can these needs be considered when planning, executing or reflecting on interdisciplinary science and social studies classes?

Research Design and Methods

Due to the not quite well understood appearance of students´ needs in interdisciplinary science and social studies and because of the necessity to describe their formation and transformation in a holistic way, several conditions for exploratory, qualitative research access are given (Corbin & Strauss, 2015, p. 5). The fundamental differentiation of the needs for autonomy, competence and social relatedness requires theoretical sensitivity on the one hand but is not sufficient only to fully describe the needs of students on the other hand. The subject of research – the appearance and consideration of needs in the context of technology education – requires theoretical enrichment. One central argument for the research approach of grounded theory (Breuer *et al.*, 2019) is the necessity for a greater focus on the needs of all different students as one key to welcome diversity and foster inclusive education. This makes it possible to constantly compare the different needs without taking traditional ways of distinguishing pupils in educational research into account (i.e. ability/disability, socioeconomic status, sex/gender etc.). A repetition of common focusses can therefore be avoided, and the reproduction of potentially discriminatory personal characteristics are reduced.

Another basic idea of the research project is to elaborate potentials and hindrances regarding the consideration of students´ needs in primary school classes through a theoretical specification of the nature of students´ needs. Advocating a broad definition of the term inclusion, this means to not especially look for the needs of students with or without impairments but to get past traditional categories and try to better understand the needs of all children. The research design's (Figure 1) location in the methodological paradigm of reflexive grounded theory (Breuer *et al.*, 2019) makes it possible to explore the appearance of students´ needs during technologically learning and aims to clarify on how different expressions of individual needs are addressed and considered by teachers. To achieve a well-reasoned sample choice (Emmel, 2013, p. 33) for future interviews, second grade students have been surveyed on their desired satisfaction of basic psychological needs during science and social studies. The project component presented here contains of first results from a pilot study of the questionnaire used.

The sample consisted of eight female and 13 male students from one second grade class in a primary school in Muenster (n = 21). To avoid the sample falling into the aforementioned traditional variables such as ability and disability, no further personal variables were collected.

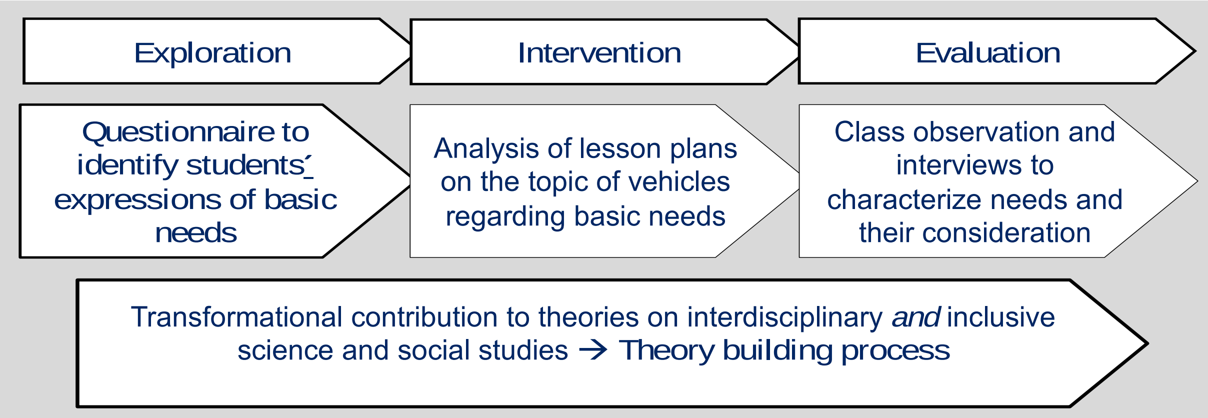

Figure 1. Research design.

Preliminary Findings

It must be mentioned that due to the small sample size, the validity of the presented results is very low. Still, they can provide information on whether the students did understand the questions provided – especially as far as a groups´ diversity is concerned. The results on the nature of children's needs are to be analysed and understood as preliminary and interpreted carefully.

As a first step descriptive statistics for the total of 37 items were calculated. Regarding the subjective significance of basic psychological needs the results show an average which is slightly above the arithmetic mean of 2.5 including all 37 items (M = 2.6178; SD =.33).
Secondly structured by the three basic psychological needs *autonomy*, *competence* and *social relatedness*, the subjective significance of the needs for competence (M = 2,7905; SD = .66) and social relatedness (M = 2,8571; SD = .79) are slightly but not statistically significant above average. The need for autonomy (M = 2,3452 SD = .64) is slightly below average.
In a third step, correlations among the three basic needs are presented after arithmetical cleansing.

The small number of polled students and especially partially unsatisfactory content validity of the implemented constructs only allow a very cautious calculation of correlations among them. The results show that the subjective significance of the need for autonomy correlates in a highly significant negative way with the need for social relatedness (r = -.507, p = .019*). Furthermore the analysis found a medium highly significant positive correlation between the subjective significance of social relatedness and competence (r = .436, p = .048*). Autonomy and competence do correlate weakly negative but not significantly (r = -.260 p = .256).

One fundamental result of this pilot study is that – as assumed – the subjective significance of basic needs seems to be divers within students and among different students. The analysis of correlations between the constructs implemented, even for the small sample size, offers the identification of various cases for further research. The findings increase the intriguing possibility that children, although of young age, differ in their individually desired arrangement of teaching and learning. The study points at the possibility that for example children who prefer a high degree of autonomy tend to find social relatedness within their class and to the teacher less important and vice versa. Putting this in the context of the study it would be of interest how these different children describe their teaching and learning experiences during technological education lessons and under which conditions they prefer rather self-determined or controlled, socially related or isolated behaviour.

Finally, for the theory-building process it is open to what extent teachers are aware of the different needs of students and what strategies are used to take them into account. It is reasonable to assume that the broad variety of contents in the concept of science and social studies as one interdisciplinary school subject in primary education might be more likely to meet the diverse needs of students than in other subjects although students´ needs are not exclusively related to the content or topic.

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3.2 Mentor Group 2 | Tulpen | 3.2.1

Teachers' Online Assessment during Emergency Remote Learning: Characteristics and Dimensions

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Keywords: Science, Secondary Education, Self-regulated Learning, Assessment for Learning

Focus of the Study

During the COVID-19 pandemic, teachers were forced to shift to emergency remote learning, and with that – to perform online assessment. Accomplishing this requires high-level self-regulated learning (SRL) and assessment for learning (AfL) skills. Zimmerman defined SRL as "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000; p. 14). Self-regulated learners plan, set goals and engage in strategies to achieve them. Alongside, Zimmerman (2000) defined self-reflection as the skill of evaluating academic, affective, and motivational outcomes of one's learning. Contemporaneously to this work, assessment for learning (AfL), coined by several authors (Birenbaum *et al.*, 2006), was defined as a perspective from which assessment is viewed as an ongoing feedback process to promote learning. AfL is defined as the opposite of assessment of learning (AoL), which perceives assessment as an instrument of summarizing students' learning outcomes for top-down decision-making purposes. Shifting to emergency remote learning (Hodges et. al, 2020) mandated both students' and teachers' SRL as well as self-regulate their teaching as nurturers of SRL evolvement in their students (Kramarski & Kohen, 2017). The current study focuses on the role of AfL as an enabler of middle-school teachers' SRL as they shift from traditional teaching to online ones. To this end, teachers' SRL levels are self-assessed via the SRLMQ questionnaire (Littlejohn et. al, 2016), which was translated and culturally adapted for the target population (for whom English is 2nd or 3rd language).

Theoretical Framework

SRL is demanded in remote learning, and even more so in emergency remote learning (Hodges et. al, 2020). Since SRL requires the high-level performance of self-evaluation, integrating external and internal feedback (Broadbent *et al.*, 2021), AfL fits it well. AfL improves SRL practice by providing the necessary feedback for assimilating successful strategies over time into the learning process. Unfortunately, the application of AfL practices is proven challenging for teachers (Avargil *et al.*, 2012), and online assessment poses even more difficulties for teachers. Kramarski & Kohen (2017) noted that the implementation of SRL in class asserts a twofold role for SRL teachers: while supporting the evolving SRL of their students, teachers must both self-regulate their own learning of new teaching tools and methods and simultaneously regulate their teaching as mentors and role models for their students, while the latter carries out their self-regulation processes. SRL research still lacks concrete methods for teachers to sustain their dual SRL role: as learners, learning and implementing SRL skills in their work, and as SRL educating teachers. As a step to remedying this deficiency, the current study characterizes teachers' perceptions of online assessment in their SRL dual role context while exploring their reflective skill.

Self-reflection in AfL context

In Zimmerman's cycle SRL model (2000), self-judgment is where learners evaluate their work and the learner judges how far the goal is achieved, referring to individual, normative, competitive, or social orientation norms. Self-judgment also includes self-actions and affective reactions to the judgments. These reactions result in adaptive or defensive decisions regarding future engagement with similar learning tasks or goals (Zimmerman, 2000). Therefore, if the following two conditions hold: (1) teachers' AfL competence generates feedback to adjust ongoing teaching and learning to improve student's achievements (Panadero, Andrade & Brookhart, 2018), and (2) self-reflection is the act of making judgments regarding one's performance in learning, and affectivity reacting to it (Zimmerman, 2000), then it follows that AfL in SRL contexts enables teachers' ability to stimulate their students to self-judge their work and affectively react to it adaptively. In the SRL context, teachers hold twofold self-judgment processes, judging and reacting to both their own professional decisions and actions and then again – supporting their students' judgments and reactions.

Research Questions

The current study aims to probe self-reflection as the linkage between the teachers' SRL and AfL while they conduct online teaching, learning, and assessment. Accordingly, the research questions are:

1. What are teachers' perceptions toward their dual learner-teacher SRL role?
2. What is the effect of teachers' SRL on their reflection practices and their students' SRL characteristics?

In this synopsis we focus only on the first research question and the findings of a pilot study, and we will elaborate on both in the main study that is currently in its infancy.

Research Design and Method

This study deploys the convergent parallel mixed-methods design (Creswell & Plano Clark, 2007), consisting of two research tools: a questionnaire and a semi-structured interview protocol for collecting both quantitative and qualitative data. The questionnaire includes adapted version of SRLMQ (Littlejohn et. al, 2016).

During COVID-19 lockdowns, in-service STEM and non-STEM teachers from high and middle school and various teaching subjects (N=84), self-evaluated their SRL levels via a translated and culturally adapted online version of the SRLMQ Questionnaire (Littlejohn 2016). Several professional teacher groups circulated the questionnaires via social media and superintendents' mailing lists. Additionally, the research team performed ten semi-structured interviews with teachers, policymakers, teachers'-trainers, and teachers'-instructors. participants completed their self-assessments and were interviewed during the early onset of the COVID-19 pandemic and during lockdowns and emergency remote learning (Hodges et. al, 2020).

Data analysis of the questionnaire's closed-ended items (5 points Likert scale) followed the data analysis of the original SRLMQ (Littlejohn *et al.*, 2016). The open-ended item data was analysed via assessment of the reflection quality system, derived from Van Manen's (1977) Levels of Reflectivity. Data from semi-structured interviews was analysed considering SRLMQ data for triangulation purposes.

Preliminary Findings

A pilot study involved 84 high school and middle school teachers from STEM and non-STEM disciplines who completed SRLMQ adapted to native language, culture, and teaching context.

About a third of the participants were STEM teachers. Ten policymakers (mostly STEM), teacher-instructors, and teachers were interviewed in a semi-structured interview developed by the research team.

The findings of the pilot study based on the SRLMQ are presented in Table 1, showing SRLMQ closed-ended item analysis from the pilot study demonstrate a relative self-reported weakness in goal-settings, help-seeking, and reflection skills of the participating teachers.

Table 1. SRLMQ results of the closed-ended part in the pilot study.

Factor #	Factor Title	Mean	SD
I	**Forethought**: self-reliance	4.4	0.8
II	**Forethought**: goal setting	**3.8**	**1.1**
III	**Self-reflection**	**3.9**	**1.0**
IV	**Performance**: critical thinking strategies	4.2	0.8
V	**Performance**: effective strategizing	4.1	1.0
VI	**Performance**: help seeking	**3.6**	**1.1**

Interview data has validated these findings. For instance, below is a quote of a participant who contemplates his ability to use SRL-promoting teaching strategies after describing a guided activity and conversation with his students, which allowed them to identify their own perceptions of the emergency remote learning.

"…This is not my goal in teaching chemistry. Also, I am not a homeroom teacher this year. But it is doable. Like.. again… it depends on the goal. Recording the lesson is a tool, a technological option. The question is – what is the lesson's goal? What do you want to achieve? It [the activity and conversation] was recreational, in a difficult hour, after a math class or an examination." (Quote 06AI400).

This quote demonstrates the speaker's perception of the process of goal setting for students' emergency remote learning. As the teacher's main goal is delivering subject-related content, the student's perception of the learning process seems irrelevant. The students may or may not identify their own perceptions of the situation. These have nothing to do with the learning goal, which is set by an exterior force – the teacher, the design of the curriculum etc. This also reflects on the teacher's perception of goal setting – he is not setting his own teaching goals, but rather, these are dictated to him.

Another quote helps clarify our finding of the relatively low score of the reflection skills. When a high-ranking technological policymaker was asked whether he instructs his department to assess their students' SRL skills, he replies:

"Firstly, yes. I mean, through reflection. I mean... during the learning process involving the project, he [the student] has to reflect. This is self-assessment, not something he needs to answer his teachers. He has to, but not in all of the elaborated subjects. I can offer [think] of one place at least. A few of them are incorporated with the reflection issue. ... But the examiner also has to be aware. The reflection is usually in the first or second level, you know, there are a few levels of reflection. […] the thing is, that it only happens during the actual [matriculation] examination. If it's a skilled examiner, they would know to ask these questions." (Quote 03HR345).

This quote shows that even when reflection skills are considered to be incorporated into the curriculum by the policymaker, they are not directly addressed during the learning process, yield low-level reflections, and are not incorporated into the next learning cycle, but rather used for AoL.

Further research will focus on teacher reflective skill development as means to achieve improvement in both SRL and AfL. The research contributions are the identification of teachers' perceptions of their dual role in SRL: as SRL learners and as SRL cultivators in their students' validation of SRLMQ in AfL context.

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3.2 Mentor Group 2 | Tulpen | 3.2.2

Metaphors in Biology Education: A Comparison between Native and Non-native German Students, Biology Teachers and Lecturers

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Keywords: Biology, Secondary Education, Metaphors, Students' Conceptions, Second Language Learners

Focus of the Study

Language is a central element of learning and essentially influences the development of students' conceptions. Students do not only have to understand the language itself but must also structure their knowledge and conceptions by using language (Beger & Jäkel, 2015; Ikuta & Miwa, 2021). Since the national language is predominant in most biology classes, students need to have a high level of language proficiency to participate. This *monolingual habitus* (Gogolin, 1997) constitutes one of the main barriers for second language learners (SLL) when attending science classes. In biology education, metaphors are commonly used to support students in understanding abstract phenomena (Aubusson *et al.*, 2006). Especially for SLL, however, metaphors might even impede students' understanding, as they must not be understood literally, but in a transferred sense. In addition, metaphors differ depending on languages as well as cultures (Danielsson *et al.*, 2018). Therefore, SLL might not understand (some) metaphors in German language. In this way, the monolingual habitus in science classes disadvantages SLL.

Recent studies focus either on students' conceptions (e. g. Gropengießer & Kattmann, 2013) or language learning within biology education (e. g. Zuckswert *et al.*, 2019). Additionally, some studies focus on metaphors within students' conceptions and/or metaphors (as tools) in science education (Danielsson *et al.*, 2018). However, currently, a connection of these two topics with respect to SLL and, moreover, possible influences of teachers' language on SLL conceptions are missing. there is no research which implements the role of SLL at the same time. Therefore, it is still unclear, to what extent different first languages influence metaphors in students' conceptions in a monolingual class.

Based on this, the PhD project aims to explore which metaphorical expressions are used by lecturers, native and non-native German students and their biology teachers to explain biological phenomena and to what extent they differ.

Theoretical Background

For the development of understanding in the context of biology learning it is fundamental to build up and explore students' conceptions, which are grounded in individual experiences (Gropengießer & Kattmann, 2013). According to Conceptual Change theory (Duit & Treagust, 2003), learning processes can initiate the active change of students' conceptions to resemble or be expanded by scientific appropriate conceptions (Schrenk *et al.*, 2019). Students are ideally enabled to switch between those two types of conceptions consciously and situation-specifically. For this purpose, it is advisable to contrast scientists' and students' conceptions as described in the Model of Educational Reconstruction by Duit *et al.* (2012).

As biological phenomena are often complex and abstract, the use of metaphors in biology (education) is common (Niebert *et al.*, 2014). According to Conceptual Metaphor Theory (Lakoff & Johnson, 2003), people use embodied, physical experiences ("source") to understand abstract phenomena ("target") in an analogical way. With respect to biology education, the study by Pettersson *et al.* (2020) shows first indications, that students adapt metaphors of their teachers and textbooks, and, additionally, use own-built metaphors to understand abstract biological phenomena. However, students often understand metaphors literally or misinterpret them (Beger & Jäkel, 2015), which results in challenges according to learning.

Since metaphors depend on cultures (Lakoff & Johnson, 2003), it can be hypothesized that the constructed metaphors of SLL differ from those of native speakers. First indications are shown in the research of Haddad and Montero-Martínez (2019) and Conrad and Libarkin (2021). However, recent research refers to chemistry, physics or geoscience education and did not differentiate on different first languages.

Research Questions

The presented study aims at exploring differences in the use of metaphors by different native and non-native German participants. Thus, the relevance of metaphors in biology education for SLL will be elaborated and first implications will be given.

To reach this goal, this explorative study answers the following research questions:

1. Which metaphorical language is used by students, lecturers, and teachers to explain biological phenomena?
2. What are the differences regarding the use of metaphorical language between native and non-native German students?

Research Design and Methods

The research design is based on the Model of Educational Reconstruction (Duit *et al.*, 2012) combined with Conceptual Metaphor Theory (Lakoff & Johnson, 2003; Schmitt, 2005). This enables me to analyse the content as well as metaphors used in a connective way. I chose guideline-based interviews to collect each participant's conceptions. Therefore, two biological phenomena were chosen: (1) decomposition of leaves as an experienceable topic and (2) being diseased by influenza as an abstract topic.

To get an overview about scientific conceptions, I structure the lecturers' interviews by Qualitative Content Analysis (Kuckartz, 2014) and analyse types of metaphors (e.g., personifications) by metaphor analysis (Schmitt, 2005). Based on these results, I obtain in which way metaphors play an important role in biology education – especially for second language learners. Afterwards, I similarly survey and analyse the conceptions of 10th grade native and non-native German students (15-17 years) as well as conceptions of their biology teachers. As a result, conceptions of all participants are structured according to content and with focus on the function of metaphors used.

Furthermore, students' and teachers' demographical data such as age, migration and language background are gathered by questionnaire. Hereby, a comparison between participants with different first languages is possible. Thus, possible influences between the teachers' and the learners' conceptions and their use of metaphorical language can be established. Quantitative analyses (descriptive statistics, correlations, t-tests, multiple regression) of the data will be conducted using SPSS.

Finally, I compare the conceptions of lecturers, students, and teachers to identify challenging and supportive metaphors for biology learning in the respective topics. This comparison leads to a discussion about implementations of metaphors in biology education.

Up to now, the data collection with respect to the lecturers (n=4) is finished and eleven students and their two biology teachers were interviewed. In addition, a minimum of four more teachers with six of their students each will be interviewed until summer 2022.

Preliminary Findings

The first analysis in terms of content of the lecturers' interviews show, that the lecturers mixed different terms with different meanings and some explanations found in science textbooks were missing within their explanations. To clarify scientific conceptions, preliminary results will be expanded by a thorough analysis of science textbooks. Afterwards, a comparison of scientific conceptions and the lecturers' conceptions will be possible. Based on the results, first suggestions about differences between written consensus and individual explanations can be made.

Based on that, I am working on a category system that will be applied on all interviews to enable comparing the different groups (lecturers, students, and teachers). However, since the explanations about the two topics strongly differ, the development of this category system turned out to be challenging.

So far, some interesting findings of the student interviews can be outlined. During an interview with a student with German and Turkish as first languages (born in Germany) and a student with Arabic as first language (born in Syria), very different conceptions occurred. While the German and Turkish speaking student explained that having influenza is caused by bacteria, the student with Arabic as a first language explained different lifestyles as reason for illness. This student did not mention the function of the immune system as an important part of our health either. Thus, it could be important to keep – next to the languages – the national background of the students in mind during analysis.

Regarding the analysis, I am currently considering about three aspects:

- According to my category system: How do I achieve a high level of comparability of the results despite the different conceptions of the participants?
- To what extent is it useful to create types regarding the use of metaphors in different first languages?
- Which language education theories can I include in addition?

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3.2 Mentor Group 2 | Tulpen | 3.2.3

Exploring Institutionally-based Chemistry Identities in Brazilian High-school Students

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Keywords: Chemistry, Secondary Education, Chemistry Identity, Social Class, Habitus

Focus of the Study

The central purpose of this research is to explore how Brazilian schools' social composition and status impact students' process of identification with school chemistry. The main hypothesis is that a school's dispositions, as a system of values, beliefs and practices reflect its social composition and positioning in relation to other schools in the same region. Therefore, the nature of students' subjectivities and self-understandings concerning chemistry might differ across schools as part of a segregated educational system.

This research is being conducted at three Brazilian public schools located at different geographical locations and with social and racial mixed compositions. One of the schools is located in a middle-class neighborhood although it attends students from mixed race and social classes. This school is usually referred to as "the best public school" in the city because of its participation in students' and teachers' awards and its evident achievement in standardized tests. The other two schools are in two low-income communities in the city, and they attend mainly students from these areas, but one of them has a more homogeneous intake profile of black and brown students, and the other one has a more mixed racial composition. Both schools were known in the city as "bad schools".

This study draws together the strands of research in science identity, science/chemistry capital, schooling, and social class to explore how accounting for the school environment can shed light on understanding disparities in how chemistry identities are developed and at the same time constrained in and by institutional practices and discourses. As institutions are differently positioned in the field of schools, then material, symbolic and discursive resources that allow the flourishing of chemistry identities might also be unequally distributed between students.

Theoretical Framework

In recent years, the analytical tools developed by a Bourdieusian knowledge have been highly influential in science education research compromised with a social-justice perspective. Researchers have worked with its main tools to account for how families' class-based dispositions can impact students' identification with science (Archer *et al.*, 2013), and how the conceptualization of a science and chemistry-specific cultural and social capital explain students' science career aspirations (DeWitt and Archer, 2015; Rüschenpöhler and Markic, 2020). Yet, there remains a gap in this literature considering an exploration of how the nature of science identity might be institutionally-based and how schools can contribute to social reproduction or reduce inequalities in science learning and identity development.

Collective influences on students' identification with science have been already studied by Archer *et al.* (2013) with the concept of "family habitus". Therefore, this research aims to contribute to this body of literature by accounting for how institutions' "self-identity" as in *this is* *how we do things around here* can explain differences in how students come to see themselves in relation to school chemistry. Considering schools not only as physical background for the development of students' science identity but as a system of values, norms, and attitudes that actively mediates their schooling experiences, this research draws on the Bourdieusian-inspired concept of 'institutional habitus' and Bourdieu's toolkit of habitus, capital and field to examine how the social context can influence on schools' functioning and learner's identity as related to chemistry.

As proposed in the social theory developed by Bourdieu, social agents are involved in a system of relations of domination at the symbolic, social, and material levels. With a focus on developing a theory of practice, Bourdieu (1987) proposes that the reproduction of systems of domination is a product of the interaction between the *habitus* as a matrix of dispositions that form agents mental and bodily schemes; the *field* as a system of objective relations in which each agent or organization occupies a defined position; and *capital* (cultural, economic and social) as a set of resources disputed and recognized as valuable by agents engaged in a field. It is the interactions between these ontological levels that explain social practices (Bourdieu, 1988).

Institutional habitus is an analytical Bourdieusian perspective on how individual schools can contribute to social reproduction by adopting different forms of organizational practices. Although habitus was originally conceived and for the most part used as an individual concept, authors such as Reay (1998) and McDonough (1996) propose to extend its heuristic value for institutions and organizations. As described by Tarabini, Curran and Fontdevila (2017), using institutional habitus as an analytical device "(...) means examining how schools are positioned in relation to their social context and how they respond to this background through a variety of organizational pedagogical devices" (p. 1180).

For instance, institutional habitus has been used to explore how schools' systems of values mediate working-class students' habitus (Ingram, 2009), its influence on the process of higher education choosing (Reay, 1998), how schools' materiality is shaped by its social positioning (Paromaa, 2017), and to explain the conflicts produced by the experience of families from disadvantaged backgrounds within a science museum (Archer *et al.*, 2016). Although there are critics and limitations about its use (Atkinson, 2011), the concept of institutional habitus can still have a heuristic value for exploring how schools produce differences in learners' identities (Forbes, 2014) and schooling trajectories. This is particularly relevant in a segregated educational system such as in Brazil (Costa and Bartholo, 2014).

Research Questions

Given its main theoretical tenets described above, the purpose of this research in answering the following questions:

1. How does institutional habitus mediate students' trajectories of identification with school chemistry?
2. What are the differences in students' process of identification with school chemistry across geographically distant educational institutions?

Research Design and Methods

Intending to explore institutionally-based trajectories of identification with science/chemistry, in its first phase, this study draws primarily on qualitative data based on (a) observations of the school environment, materiality, routine, practices, and discourses, (b) observation of chemistry classes, (c) individual interviews with chemistry teachers and school's headteachers, (d) focus group with high school students, and (e) readings of schools' documents.

In the second phase of research, which is under preparation, we want to focus on a small sample of students from the three participating schools who had previously engaged in the initial focus groups. The selection will be based on students' gender, racial, and social class identification, their achievement, and how they had earlier described their interest in chemistry as revealed by previously collected data. Students selected will be individually interviewed repeated times throughout one year of schooling. As was the case in the first phase of research, chemistry classes and informal pedagogical practices will also be observed. In this case, the focus is particularly on students' engagement with chemistry lessons and interactions with teachers and peers. As a way of developing a more fine-tuned analysis of schools' dispositions, chemistry teachers and headteachers will again be interviewed one more time. In this phase, focus groups will be conducted at each school with a broader sample of teachers from the natural sciences to identify more precisely the school's attitude towards these areas.

Preliminary Findings

The initial data collection was done throughout approximately four months between September and December of 2021. The researcher visited the three schools at least one or two days a week. During this period, a total of 63 hours of observational data was collected with detailed field notes of the schools' environment and routines, chemistry classes, and staff meetings. The researcher also spent time in the staff's room and hallways and had informal conversations with some of them about the school. In each school, individual semi-structured interviews were conducted with three chemistry teachers and two headteachers. Students in their first year of high school were invited to volunteer for participation in focus groups or individual interviews. A total of 50 students participated in 13 focus groups. Two students in one school participated in individual semi-structured interviews.

Initial data analysis is still in progress. Individual and focus group interviews are being transcribed in an electronic document. Teachers', headteachers', and students' interviews will be initially coded inductively to explore how they embody institutional norms, values, and beliefs. Field notes will also be coded inductively to account for how institutions' dispositions are materialized in the schools' routines and particularly in chemistry classes. These provisional codes will then be related to a Bourdieusian framework with the purpose of producing themes by performing a thematic analysis (Braun and Clarke, 2006). The main focus, however, is analyzing how students negotiate their class habitus with what is inculcated by schools. By linking students' subjective experiences in chemistry learning with the objective conditions by which the discipline is framed, the concept of institutional habitus will be analytically used to explore how the nature of students' chemistry identity is conditioned by schools' culture and practices.

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3.2 Mentor Group 2 | Tulpen | 3.2.4

Development of a Curriculum Design on Energy Transfer in Electrical Systems for Upper Secondary School Students

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Keywords: Physics, Secondary Education, Design-Based Research, Electricity, Electromagnetic Fields, Energy

Focus of the Study

It is known from physics education research that many students hold persistent misconceptions even after they have been taught in the field of electricity. These include misconceptions about energy in electrical systems (e.g. Engelhardt & Beichner, 2004).

Moreover, students have difficulty describing the physics of energy transfer (the directional energy flux) in simple electrical systems, even though they use electrical devices on an everyday basis. To address this problem, a new design-based-research project has been initiated. Its aim is to develop and evaluate a new curriculum design for upper secondary school students (aged 16-17) for the Austrian curriculum that uses electromagnetic fields to explain the energy transfer in electrical AC and DC circuits.

Theoretical Framework

The physics of energy transfer in electrical systems is very complex (e.g. Chabay & Sherwood, 2007). To describe it properly, one has to understand, that energy (e.g. in a simple electrical circuit, consisting of a battery, two cables, and a light bulb) is transported by the electrical and magnetic fields in the surrounding area of the wires and that surface charges are responsible for the generation of the electric field (e.g. Jackson, 1996). In Physics, the directional energy flux (the energy transfer per unit area per unit time) is described by the Poynting vector, a cross product of the magnetic and electric field (Poynting, 1884). Some physics education researchers suggest the use of electromagnetic fields to describe how energy is transferred in electrical systems (Backhaus, 1987; Rückl, 1991; Sefton, 2002), but in many curricula, this topic usually plays no or only a subordinate role. Although there are some educational materials on electromagnetic fields (and the associated Poynting vector) and on electric fields (which are attributed to the presence of surface charges), they are often not suitable for the Austrian physics curriculum at secondary school level (e.g. Chabay & Sherwood, 2007; Rückl, 1991).

This shows that there is a research gap, as there is no teaching approach for energy transfer in electrical systems for the upper secondary school level in German speaking countries that can help students to better understand this topic and deal with misconceptions. Furthermore, it must be explored, to ascertain if an approach using electromagnetic fields at a secondary school level can be used to increase understanding. Even though fields are often considered complex topics, they are also a basic requirement for understanding Physics, similar to the concept of energy. Thus, a curriculum design based on field theory could provide a good opportunity for additional practice on this topic.

Research Questions

As stated above, this study aims to develop a new curriculum design on the physics of energy transfer in electrical systems. For this purpose, the following research questions (RQ) were formulated:

1. Does the newly developed research-based curriculum design on energy transfer in electrical systems, that is based on a set of specific design principles, support upper secondary school students in developing adequate ideas about this topic?
2. How do student misconceptions, errors, and misunderstandings about the physics of energy transfer in electrical systems differ with students who have been taught traditionally and students who have been taught with the new teaching approach?

Research Design and Methods

The development of the new curriculum design on energy transfer follows the design-based-research-model (Haagen-Schützenhöfer & Hopf, 2020). To answer the first research question, design principles were created as a baseline for the curriculum design. For example, one domain-specific design principle states that learning processes should be embedded in contexts that are interesting for students. This goes back to the model of educational reconstruction (MER) (Kattmann, Duit, Gropengiesser, & Komorek, 1997) which was also used to create elementary basic ideas, so-called 'key ideas'. These were based on literature research and form the first step of this curriculum design.

In the next step, the key ideas were used to create an interview guide that was used for interviews using the method of probing acceptance. This method goes back to Jung (1992) and was further developed by Wiesner and Wodzinski (1996). Usually, interviews follow a four-step process. First, the interviewee is presented with an explanation from the interviewer. This may refer to a key idea or involve an experiment. For example, in the first round of interviews, a simple electrical circuit (consisting of a battery, two wires and a fan) was shown to the interviewee. A current clamp was held around the wires of the circuit, indicating a positive value, provided the circuit was closed and a current was flowing. This was explained by the presence of a magnetic field around the wires, which is formed when charges move within. Second, the acceptance of the explanatory model is assessed using a format such as "Was this understandable to you?". If necessary, the explanation can be repeated at this point or questions can be asked by the interviewee. Third, the interviewee is asked to repeat the explanation him or herself. Attention is paid to which terms are used. Forth, one or more tasks are then given to assess deeper understanding of the topic. For example, an interviewee might be asked to describe the energy flow for an electric hair dryer instead of a table lamp. The four-step process is repeated for each key idea or experiment so that the entire interview follows a similar structure.

So far, the first round of interviews has been conducted with seven 11th grade students (aged 16-17 years). The results of the interviews have been transcribed and analysed using a qualitative content analysis (Kuckartz, 2016). A 'traffic light system' was used to indicate when a statement was coded as completely correct (green), almost correct (yellow) or incorrect (red). From the analysis of the interview data, it can be concluded which parts of the interview were problematic for the interviewees and whether these were individual cases. Based on this information, the interview guide has been revised for the next round of interviews by adapting tasks and key ideas. This cyclical process of design and re-design is repeated several times, with new conclusions about the acceptance of the key ideas being drawn in each round. These findings will be used to develop a set of consistent design principles, based upon which the final curriculum design is formed.

Preliminary Findings

The evaluation of the data shows that the concept was generally well perceived by the students. Difficult passages from the interview transcripts, that were coded yellow or red, indicate which revisions are necessary for the next round of interviews. For example, distinguishing between magnetic and electric fields seems to be a difficult task for some interviewees. However, when the fields are addressed one by one, the students seem to have no trouble using them in their explanations. This was considered to revise the interview guide for round 2 by adding a 'cognitive stop sign' in relevant passages. For example, the interviewee is told to pay attention to which field is being referred to during the discussion.

In addition, the results show that the electric field in open circuits should be explained in more detail during the interviews. For this, a new key idea was added as an intermediate step to the interview guide.

These implications are currently used for the second round of interviews, which will take place at the beginning of 2022. After analysis of this round, a third interview round will be planned and conducted. Following the interviews, a new curriculum design with materials will be developed and tested in real classroom settings. A pre- and post-test design is planned to answer research question 2.

The results from both research questions will help to develop a local instruction theory about teaching and learning about the physics of energy transfer in electrical systems that can be regarded as a set of consistent research-based, domain-specific design principles (Haagen-Schützenhöfer & Hopf, 2020).

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3.2 Mentor Group 2 | Tulpen | 3.2.5

Supporting Pre-Service Teachers' Learning of Computational Thinking through Designing a Computational Thinking Integrated Course

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Keywords: Science, Elementary Education, Pre-service Teacher Learning, Computational Thinking

Focus of the Study

Science and engineering education at the K-12 level in the United States is currently guided by the Next Generation Science Standards (NGSS) in 44 states and the District of Columbia. One of the eight science and engineering practices (SEPs) in NGSS is "Using mathematics and computational thinking" (NRC, 2012). According to Wing (2006), Computational thinking (CT) can be defined as "solving problems, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science" (p. 33). Weintrop and colleagues (2015) developed an actionable and classroom-ready taxonomy for CT practices in mathematics and science classrooms. These CT practices include data practices, modeling & simulation practices, computational problem-solving practices, and systems thinking practices.

Prior research investigating science teachers' preparedness and motivation to implement SEPs shows that teachers do not feel ready to integrate CT into their classes (Haag & Megowan, 2015). To meet this need, several scholars have integrated CT into undergraduate classes. This integration takes multiple forms, from integrating a CT module that takes a couple of hours (Walton *et al.*, 2020: Yadav *et al.*, 2011) to re-designing an undergraduate class by incorporating CT (Mouza *et al.*, 2017). These approaches show success in supporting pre-service teachers' (PSTs) understanding that CT can be taught in different disciplinary contexts without using computers (Yadav *et al.*, 2011). However, the results overwhelmingly demonstrate that PSTs usually made keyword-based connections between components of CT and science curricula (Walton *et al.*, 2017) and they were largely unable to develop lesson plans that meaningfully incorporated CT with disciplinary content (Mouza *et al.*, 2017). The PSTs' understanding of CT fell short of showing how CT supports science learning (Walton *et al.*, 2020). Thus, there is an urgent need to advance PSTs' understanding of CT as a form of scientific epistemic (e.g., knowledge-making) practice.

Review of Literature | Theoretical Background | Theoretical Framework

In this paper, I draw on epistemic practices as "specific ways members of a community propose, evaluate, and legitimize knowledge claims within a disciplinary framework" (Kelly, 2008, p. 99). Epistemic practices are relevant to producing and evaluating knowledge claims. Thus, integrating CT as a form of reinforcing what is already known does not count as utilizing CT as an epistemic practice since it does not involve producing or justifying new knowledge.

Research (Mouza *et al.*, 2017; Walton et al, 2020) shows PSTs have a challenging time integrating CT as a form of epistemic practice. Compared to other SEPs (e.g., engaging in arguments from the evidence, planning an investigation), CT is relatively new to educators so that most teachers did not experience authentic CT practices in their K-12 learning. However, as Kuhn and colleagues (2017) show, engaging in scientific practices promotes a better understanding of them. A second reason for the challenges is that the role for CT in service of science learning is unclear to teachers. A recent literature review on teacher learning of computational thinking show CT was rarely integrated into the science classes to meet epistemic goals such as exploring scientific concepts in different ways, more often CT was integrated as a means for reinforcing declarative knowledge (Tosun & Farris, 2022). These non-epistemic rationales for CT-integration ultimately distract from the potential for CT to support science learning.

To meet these challenges, a college-level STEM content course was re-designed by integrating CT. This class entails four initial overarching design aspects. First, as Fishman and colleagues (2014) suggest, successful professional development requires prolonged participation. Therefore, as opposed to previous studies in which CT was introduced through one-shot workshop (e.g., Walton *et al.*, 2020; Yadav *et al.*, 2014), in this study CT is integrated into the course as a SEP that is enacted across different modules through the semester. Second, as stated before, I draw on science learning as participation in epistemic practices so that, at each module, CT practices were used to explore a particular physics concept or to solve an engineering design challenge rather than reinforcing what is already known (will be detailed in methods). Also, I conjecture that participation in these authentic CT practices will promote a better understanding of them based on the previous literature (Kuhn *et al.*, 2017). Finally, CT aspects of learning activities will be made explicit to PSTs. This is crucial since learners may not spontaneously make the connections that are intended by the researchers or curriculum developers (Cunningham, 2017).

Research Questions

1. Following participation in semester long CT integrated activities, what is the nature of PSTs' beliefs about CT integration in their future science classrooms?
2. How do engaging in CT practices facilitate & support learning of physics and solving engineering design challenges?
3. What are the design properties of a CT integrated STEM course designed for supporting PSTs' learning of CT?

Research Design and Methods

Setting & Course Design

This study will draw on methods from design-based research which attempts to develop and enact intentionally designed tools, instructional designs, activity structures in complex real-life settings and iteratively refine them (Bell *et al.*, 2004).

The study takes place in an undergraduate introduction to engineering course occurring in Spring 2022 at a large land grant university in the northeastern United States. The class meets twice a week for 75-minutes for 15 weeks. This introductory and interdisciplinary course focuses on physical science concepts, pure and applied science and scientific processes, engineering design principles, and associated technologies. The course is designed in four modules: structures, simple machines, electricity, and making and modeling with code. In Week 1, I introduced CT and CT practices in a 50-minute presentation with examples of CT integrated science activities. In the following four modules, CT is integrated to pursue epistemic goal. For example, in the structures module, PSTs will use computational modeling software to improve their physical bridge design made of K'NEX parts. The software displays a table including the data about the length of each member as well as the forces acted on each member. By analyzing this data, PSTs may improve their physical design, which is an example of modeling & simulation practices and data practices within CT (Weintrop *et al.*, 2015).

Participants

All registered students (N=25) who consent to participate are potential participants of the study. Twenty-two of the 25 students are majoring in Early Childhood and Elementary Education.

Data Collection and Analysis

Data collection is woven throughout the semester and includes student assignments, detailed instructor field notes, and semi-structured interviews at the end of the semester. At the end of each module as a part of their assignment, they will be asked to reflect on CT practices that they used in the module and how engaging in those CT practices supported their learning of a physics concept or to solve an engineering design challenge. Open and axial coding (Strauss & Corbin, 1990) will be used for data analysis of PSTs' reflections and field notes as I try to understand in what ways CT supports PSTs' learning of scientific concepts or solutions to engineering design challenges. Additionally, following the 50-minute introduction in Week 1, PSTs were asked to create an image that depicts elementary-aged students' engagement in CT in a science or engineering activity and explain how the activity in their drawing involves CT and how the CT in the activity supports learning. In the final week, PSTs will complete the same task again. These drawings will be analyzed using thematic coding from a deductive approach (e.g., CT integration for epistemic goals, CT integration for non-epistemic goals) (Braun & Clarke, 2006).

Preliminary Findings

To eliminate the coercion of students, I will ask for their consent to participate in this study after grades are posted. Thus, students' Week1 responses to the drawing prompt are available now, but I cannot use them at this point since I do not have PSTs' consent. However, as the instructor of the course, I am observing that the CT components in the course content (as I recognize them) helps the PSTs to make sense of a scientific problems they face in the course, but at this point, it is unclear to what extend PSTs are noticing these components and how these components help them to reach their epistemic goals.

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3.2 Mentor Group 2 | Tulpen | 3.2.6

Design and Evaluation of Context-based Teaching Resources for Simple Electric Circuits

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Keywords: Physics, Secondary Education, Electric Circuits, Context-based Learning

Focus of the Study

Apart from teaching subject content, school education also aims to arouse learners' interest in the subject and thus create the foundation for intrinsically motivated engagement. This is of particular relevance in physics because studies show a decrease in students' interest during their time in school (e.g., Merzyn, 2008). In addition, physics is overall considered as one of the least popular subjects, especially among girls (Muckenfuß, 2006). Students' aversion to physics is particularly problematic in the field of electricity as it forms the backbone of our modern society. Against this backdrop, the EKo project ("Electricity with Contexts") aims to investigate how the approach of context-based teaching affects the learners' interest, their conceptional understanding and their physics-related self-concept.

Building on preliminary work on related approaches (Dopatka *et al.*, 2019; Elster, 2007; Hoffmann *et al.*, 1998), we developed context-based teaching resources for a unit on simple electric circuits (usually taught in grade 8). The resources include a textbook and additional digital resources to facilitate teachers' implementation of the concept. A central objective of the design was that teachers can integrate them easily into traditional lessons on simple electric circuits. In addition, our main motivation to develop the teaching resources was that hardly any empirically evaluated context-based teaching resources exist so far on the topic of simple electric circuits. Each chapter of our context-based textbook focusses on a specific application-related question. The students' learning process in each chapter is hence intended to be guided by this question, e.g., whether electric eels are dangerous for humans. By making references to various types of contexts, the teaching resources aim to make physics more interesting especially to girls.

The project is part of the Design-Based Research project "Electricity with Potential - Electricity with Contexts" (EPo-EKo) of six universities from two countries.

Theoretical Background

Integration of contexts into physics lessons has long been considered important and is firmly anchored in national education guidelines (e.g., KMK, 2004). Numerous studies show that secondary school students' interest in physics declines with age (e.g., Merzyn, 2008). However, from analyses based on the IPN interest study (Hoffmann *et al.*, 1998), we know that it is contexts and applications that primarily determine whether students develop an interest in the school subject and not the content itself (e.g., mechanics, optics). Therefore, it is important that physics lessons take the findings from research on students' interest into account.

Both the IPN study (Hoffmann *et al.*, 1998) and the ROSE study (Elsner, 2007) investigated which types of contexts students are generally interested in. Overall, contexts related to medicine and biology as well as contexts with a societal background were reported as attractive.

However, technical contexts which are widespread in textbooks are of interest only to a small percentage of students, predominantly boys. Building on these findings, we identified topics that students generally find interesting in the field of electricity (e.g., electric eel, geoelectrics).

Although results from previous studies show that context-based teaching has a positive influence on affective factors such as interest and motivation, it is unclear whether context-based teaching also leads to a better conceptual understanding (Taasoobshirazi & Carr, 2008).

Research Questions

The PhD project focusses on answering the following research questions: How does the use of context-based teaching resources on simple circuits influence

1. the students' conceptual understanding;
2. the students' interest (both overall interest in physics and interest in physics as a school subject);
3. and the students' physics-related self-concept?

Concerning the first question, two mechanisms are conceivable: On the one hand, it can be argued that the effect is likely to be negative since working with contexts requires extra time and cognitive resources. On the other hand, it can be argued that by working with contexts, students could be overall more motivated and willing to engage more with physics content. Regarding the second research question, we expect a positive influence of context-based teaching on students' interest. This is because we deliberately selected the contexts based on existing research findings from interest studies. Concerning the third question, we are particularly interested in whether we can replicate previous research findings that the self-concept of girls increases when taught using context-based teaching resources (Häußler & Hoffmann, 1995; Lubben *et al.*, 2005).

In addition, the research project also aims to investigate whether the new context-based teaching resources are accepted and considered as helpful by teachers. This question is crucial for innovations in education because the acceptance of practitioners is an important requirement for bridging the often-lamented research-practice-gap.

Research Design and Methods

Before teachers started using the final version of the context-based teaching resources during the actual study in high schools, we first interviewed students to find out whether the teaching resources match their interests. After the first draft of the teaching concept was finished, three teachers were asked to teach the unit on electric circuits using our teaching resources. Subsequently, the respective teachers provided feedback on the use of our resources in real-life classroom situations to further refine the concept.

The teachers who participate in the actual study teach the unit on electric circuits twice: In the first term, they teach electric circuits in their accustomed manner. In the second term, they design their lessons using the provided context-based teaching resources (with then other students). This design allows us to control for the influence of the teacher since the traditional teaching serves as a baseline for the effects of the intervention group. Following the collection of empirical data, we intend to conduct follow-up surveys with the participating teachers once they finished the second term to understand the underlying mechanisms that explain the empirical results. Overall, we expect the EKo project to be completed by 2023.

We assess the students' conceptual understanding using a new test instrument developed as part of the EPo-EKo project (Ivanjek *et al.*, 2021). This diagnostic test uses only two-tier items. This means that learners not only have to answer a question (on tier 1), but also need to explain their answer (on tier 2). Because of the two-stage-design, the test instrument combines the advantages of a quantitative, psychometrically valid multiple-choice test with insights into learners' alternative conceptions that could otherwise only be uncovered through time-consuming qualitative interviews.

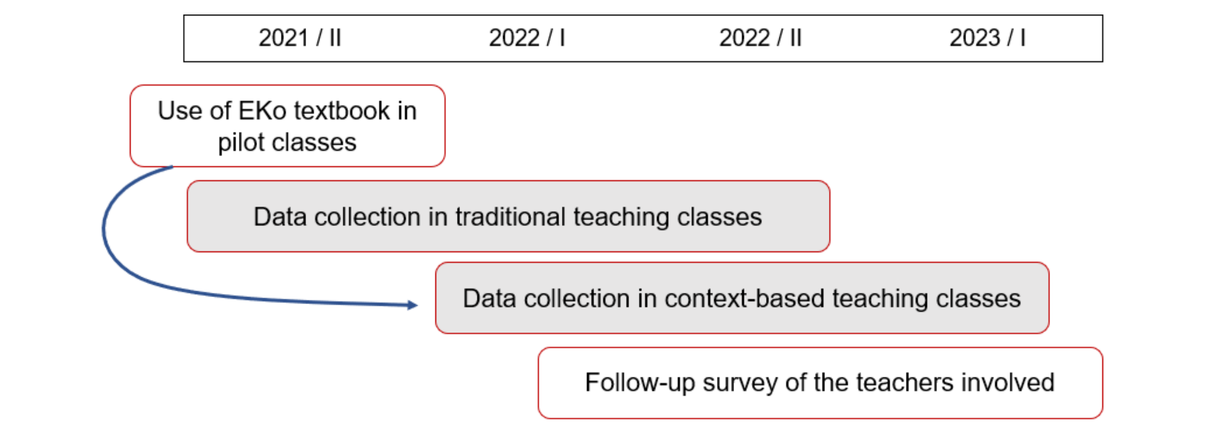

Figure 1. Schedule of the EKo project (Roman numerals indicate calendar half-years).

In addition to conceptual understanding, we also assess the students' interest in both physics generally and in physics as a school subject, their physics-related self-concept, and their verbal and figural reasoning ability. The test structure, which is identical for the traditional as well as for the context-based teaching, is shown in Figure 2.

This research project represents a quasi-experimental field study. The learners will be tested before the start of the unit on electric circuits (pre-test), after the unit on electric circuits (post-test), and ten weeks after the end of the unit (follow-up-test). The valid and reliable test instruments are designed in multiple-choice format. As outlined in Figure 2, all constructs are tested in the pre-, post- and follow-up-test except for the verbal and figural reasoning ability, which is only assessed in the pre-test as it is assumed to be temporally stable. Conceptual understanding is assessed using an anchor test design with eleven items in the pre-test and 18 items in the post- and follow-up test. We plan to evaluate the data using Rasch model and multilevel analysis.

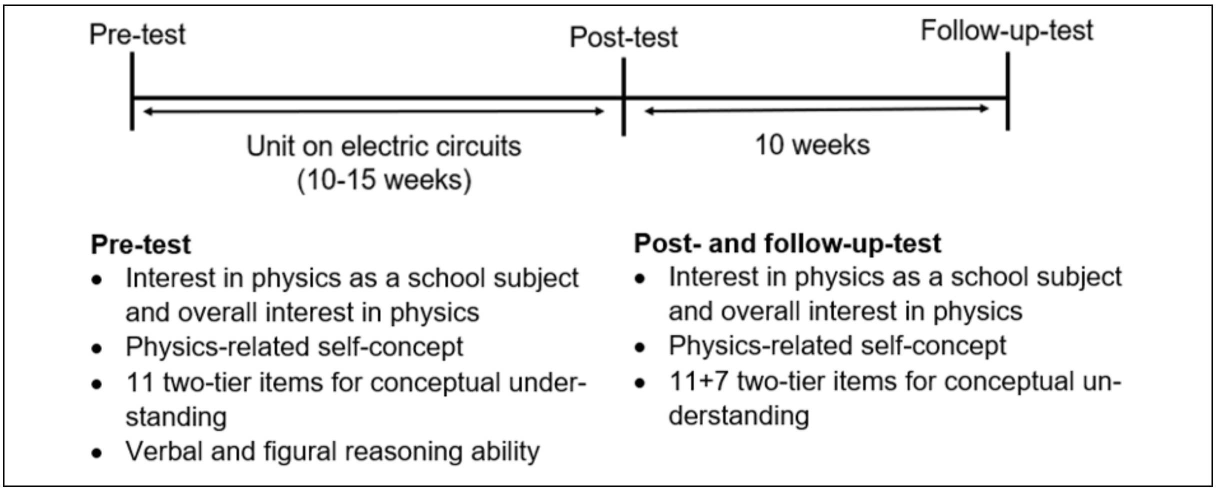

Figure 2. The test design within the EKo project.

To keep track of the content covered by teachers in their lessons, participating teachers are asked to fill in a so-called teaching diary after every lesson. On the one hand, this helps us to get access to how teachers "traditionally" teach the unit on electric circuits during the first term of data collection. On the other hand, the teaching diaries enable us to reconstruct the teachers' usage of our context-based resources in the second term.

Preliminary Findings

Apart from qualitative data from the interviews with students and teachers on the experience of learning with contexts as described above, no data has been comprehensively collected yet. However, at the time of the summer school, a substantial amount of data from the core study will be available: By summer, around 25 classes will have finished the traditional and 10 classes the context-based teaching approach. This is sufficient to present and discuss substantial preliminary findings on the effects of context-based teaching during ESERA summer school.

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3.2 Mentor Group 2 | Tulpen | 3.2.7

A Flipped Instructional Framework for Effective Learning of Organic Chemistry in Nigerian Secondary Schools

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Keywords: Secondary Education, Organic Chemistry, Flipped Instructional Framework

Focus of the Study

Organic chemistry has been consistently identified as a difficult concept for students worldwide (Cha & Kim, 2016; O'Dwyer & Childs, 2017), resulting for example, to low learner performance in the subject. One of the significant responsible factors is that organic chemistry teaching uses a teacher-centred strategy that offers little room for active student participation (Akpokiere *et al.*, 2020; Ezeudu, 2013). Therefore, there is a need for the utilization of active learning strategies in organic chemistry. Amongst the strategies is the flipped classroom strategy wherein students are given class materials before class, and the class time is used, for example, for discussion, problem-solving, and practical work (Abeysekera & Dawson, 2015; Smith, 2013). The flipped classroom strategy can help alleviate students' low performance in secondary organic chemistry, However, evidence of the implementation of the flipped classroom strategy in Nigerian secondary school organic chemistry teaching is currently lacking. Specifically, there is no framework that supports the implementation of the strategy (Diningrat *et al.*, 2020; Lo *et al.*, 2018). Therefore, the study aims to develop a flipped instructional framework for effective learning of organic chemistry in Nigerian secondary schools and provide evidence of its impact on students' learning achievement and self-efficacy linked to organic chemistry learning in Nigerian secondary schools.

Review of Literature | Conceptual Framework

Laleye (2015) suggested a paradigm shift in science teaching in Nigerian schools from the current teacher-centred teaching and learning environment to a student-centred approach where teaching and learning are enhanced using technology and students can acquire the proper knowledge and skills needed for the 21st century. The use of technology-based instructional strategies such as the flipped classroom has been identified as significantly involving the students during teaching and learning, which enhances their psychomotor skills (Sezer, 2017). Although, studies have reported inappropriate teaching methodologies, inadequate knowledge of the subject matter, unavailability of teaching-learning resources in many schools, and ineffectiveness of practical activities (Aderonmu & Obafemi, 2015; Ogbeba, 2010; Omorogbe & Ewansiha, 2013) in Nigerian schools. This is an option available to schools with access to adequate education technology. Several studies have found that students taught using a flipped classroom instructional strategy have a high achievement rate in chemistry (Fautch, 2015; Olakanmi, 2017; Schultz *et al.*, 2014; Wasserman *et al.*, 2017). Few studies have reported that the use of technology such as computers and the internet increases self-efficacy and positively correlates to students' assessments and grades (Hommes & Van der Molen, 2012; Wang & Wu, 2008; Zheng *et al.*, 2009). Also correlated to the strategy is students' self-efficacy (Kenna, 2014; Namaziandost & Çakmak, 2020; Samiee-Zafarghandi, 2018). In order to effectively implement the strategy to increase learner achievement and self-efficacy in the context of organic chemistry in Nigeria, there is a need for a suitable instructional framework that can serve as a tool for the teachers.

Conceptual Framework

The development of the framework was conceptualized based on the Context, Input, Process, and Product (CIPP) evaluation model. This model was selected to guide the formative and summative evaluations of the developing flipped instructional framework(Fitzpatrick *et al.*, 2011; Stufflebeam, 2003). The CIPP model is a four-stage evaluation model: context, input, process, and product. The context evaluation stage helps understand the basic problems, needs, and resources available to provide a befitting educational artefact (Mertens & Wilson, 2012). An appropriate artefact, in this case an instructional is prescribed at the input evaluation stage to address the needs identified at the context stage (Fitzpatrick *et al.*, 2011). At the process evaluation stage, the instructional framework is being implemented (Ivan, 2015), monitored, documented, and assessed (Mertens & Wilson, 2012). In the product stage, the impact of the framework on the targeted audience in terms of both positive and negative effects (Mertens & Wilson, 2012) coupled with the intended and unintended outcomes will be determined (Stufflebeam, 2003).

Research Questions

The research questions addressed in this study are following:

1. What are the circumstances surrounding the teaching and learning of organic chemistry in Nigerian secondary schools?
2. What are the characteristics of a generic instructional framework for implementing flipped instruction in any secondary school science subject?
3. What are teachers' perceptions of and experiences after implementing the flipped instructional framework to support effective learning of organic chemistry in Nigerian secondary schools?
4. What is the impact of the flipped instructional framework on the students' characteristics (achievement and self-efficacy) in learning organic chemistry in Nigerian secondary schools?

Research Design and Methods

The study used mixed methods in action research based on a pragmatic philosophical perspective. The philosophy was based on the fact that a study's research purposes are major factors in determining a study's philosophy (Zefeiti & Mohamad, 2015). In order to provide better and suitable solutions to the identified research problem (Sharma *et al.*, 2018), this study was carried out using the convergent parallel design of a mixed-methods research design where quantitative and qualitative data will be concurrently collected and analysed during each stage of the study (Creswell & Clark, 2017). Descriptive and inferential statistic methods will be used to analyse data from the quantitative aspect, while thematic analysis will be used to analyse data from the qualitative part.

Preliminary Findings

The quantitative data were analysed with descriptive and inferential statistics, while qualitative data were analysed thematically using Leximancer statistical tool. The data analysis was categorized into three sections: teachers' needs, resources available, and the problem encountered during teaching. The study revealed that chemistry teachers agreed that there is a need for a well-equipped laboratory, 3-D resources, a functional IT laboratory, a framework for incorporation of IT resources, and professional development sessions. They also stated that available resources are whiteboard, textbooks, improvised materials, and internet facilities. The study also revealed that chemistry teachers' most significant problems in organic chemistry teaching were the inadequacy of good textbooks, charts, models, and technological resources, students' readiness, lack of models, and inadequate teaching schedule. These findings was used to guide the second stage of the research in developing a flipped instructional framework.

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3.3 Mentor Group 3 | Windmolens | 3.3.1

Enhancing Discussion during Physics Problem Solving – Developing Cooperative Tasks in Smart Learning Environments

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Keywords: Physics, Tertiary Education, Cooperative Learning, Computer-supported Collaborative Learning

Focus of the Study

The focus of this study is how to promote high-quality and effective cooperative learning of university-level physics when working in a smart learning environment. An increasing proportion of tertiary education takes place in a smart learning environment that allows, among other things, an automated evaluation and feedback. The use of such smart learning environments gives teachers more time to interact with students and provide guidance when the environment does the mechanical work associated with the assessment.

Even if learning takes place in a smart environment, it is important to take care of communality as interaction with peers improves student engagement (Korhonen *et al.*, 2019). One way to support communality is to use learning methods that make students interact with each other, e.g. cooperative learning. In cooperative learning, students work in small groups towards a common goal, help each other to learn, and have positive interdependence (Davidson & Major, 2014).

In order for learning outcomes to be good and students perceive studying as meaningful, it is important to use appropriate tasks. Open-ended tasks that have no one right answer or specific procedures to follow have been noticed to contribute high-level interaction between students better than closed-ended tasks (Gillies, 2014). Therefore, open tasks should be favored in cooperative learning.

When it comes to physics, usually problems found in textbooks require computing and solving equations. This kind on problems have only one right answer that can be found in only a few different ways. Such problems are ideal for smart leaning environments as an automatic evaluation is easy to program, but at the same time they are not the best choice for cooperative learning. To promote higher-level interaction, tasks need to be more open. On the other hand, tasks should be simply enough so the possibilities of smart learning environment can be used.

Even if physics is an exact science, it is possible to design tasks to be open. To support student interaction and keep learning effective, we need to know what type of tasks contribute to high-quality interaction that promotes learning. The aim of this study is to find out how the type of task affects the interaction between university students when they are solving physics problems. Results can help teachers to choose and design appropriate tasks when they use cooperative learning and smart learning environments.

Theoretical Background

Student discussions have a significant role in cooperative learning as the learning outcome have been noticed to depend on the quality of discussion and argumentation (Chinn *et al.*, 2000).

One way to affect the discussion is to choose appropriate tasks that require students to think aloud and share thoughts with each other. Open-ended tasks without right answers have been showed to improve the level of interaction and thus leading to better learning outcomes than closed-ended tasks with specific answers and procedures to follow (Gillies, 2014).

Horn (2012) has presented criteria for mathematics tasks suitable for being solved in a group. According to these criteria, the task should require interpretation and provide more ways than one to succeed in solving it. Different interpretations and solutions foster productive discussion and force students to justify their ideas, which promotes learning. Due to similarities in physics and mathematics, these criteria can be applied also for physics problem posing in cooperative learning.

Even if physics is an exact science, there are many ways to design more open questions and promote productive discussion between students. Instead of asking what the right solution is, it is more appropriate to pay attention to the process that precedes the solution, e.g. asking how the problem can be solved and why the solution is correct. When using multiple-choice questions, the alternatives should contain incorrect answers that students see plausible, and the question should require higher-order thinking skills (Bjork *et al.*, 2015; Kulikovskikh *et al.*, 2017). Tasks can also be inquiry-based, allowing students to design a data acquisition process themselves and draw conclusions based on their findings (Pedaste *et al.*, 2015). In smart learning environments, simulations can be used instead of real laboratory experiments (Triona & Klahr, 2003).

Research Questions

To make cooperative learning in smart environments effective, we need to know what type of tasks support the constructive cooperation in such environments. The tasks should be open enough to promote productive discussion and simply enough to be automatically evaluated. The challenge is to find a balance between these two characteristics.

The aim of this study is to find out what kind of tasks contribute high-quality discussion that promotes learning when students are working in small groups to solve university-level physics problems in a smart learning environment. Research questions are as follows:

1. How does the type of task affect the discussion between students?
2. What are students' experiences about the suitability of the task type for cooperative learning?

Research Design and Methods

Six different physics-related tasks were developed for the study and implemented in a smart learning environment. These tasks included multiple choice questions about physics concepts and effects, calculations, drawing and searching information. The level of openness varied by the task. In the most closed-ended task, students were asked to solve the equation and calculate the answer, while in the most open-ended task students could make decisions that affected the course of the task, seek information, and wonder if their results are realistic. Some tasks did not require solving a problem completely but thinking possible ways to solve it instead. Multiple-choice questions were designed to promote discussion by selecting typical misconceptions as wrong alternatives.

Tasks were part of a university-level physics course in which students worked in small groups that remained the same throughout the course. The course followed a prime-time learning model that includes four weekly recurring parts: individual studying, cooperative learning session, meeting with the teacher and independent exercises (Koskinen *et al.*, 2018). For two consecutive weeks, the participants of the course solved the tasks developed for this study in cooperative learning sessions. The number of tasks were three per week. During these two weeks, the sessions of nine student pairs were videotaped. One session lasted approximately an hour and a half.

In both weeks, all participants of the course were asked to respond to a survey aimed at discovering students' experiences about the suitability of the task types on cooperative learning. In the survey, the same questions were asked about every task solved in cooperative learning sessions. Questions were answered by using a seven-point Likert scale. Students were asked to answer the survey independently.

Both qualitative and quantitative methods are used in this study. To answer the first research question, the videoed students' discussions related to each task are transcribed and analysed using content analysis. Discussions are classified according to their level of cooperation. After the classification, we will examine whether there are any similarities in the discussions related to each task between different student pairs. For the second research question, survey answers are analysed using statistical methods.

Preliminary Findings

Data for this study was collected in September 2021. It includes video tapes of nine student pairs solving problems in two different sessions, and survey answer from the first (n = 60) and second weeks (n = 51). Videos have already been watched through once and based on that, every task caused discussion in all pairs. At this point, a more detailed description of discussions and the impact of the task type on them cannot yet be given.

Based on the preliminary analysis of the survey, students experienced that there are only minor differences in the suitability of different types of tasks for cooperative learning. On average, students' experiences were positive. Students thought that in the case of one multiple choice task and tasks that included mainly solving equations and calculating, working cooperatively with a pair did not support learning as much as it supported for other tasks. However, they thought that in the other week's calculation task, cooperation did not made learning harder as much as it made in other tasks. These results are based on the average values of responses and no further statistical analysis has yet been done. By the time of the summer school, the analyses to answer the research questions have been finalized.

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3.3 Mentor Group 3 | Windmolens | 3.3.2

Students' Understanding of Emergent Processes in Physics within the Context of the Particulate Nature of Matter

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Keywords: Physics, Secondary Education, Particulate Nature of Matter, Design-based Research

Focus of the Study

The particulate nature of matter is considered to be a key concept in science education (National Science Teaching Association, 2017; OECD, 2019). Even though students are usually familiar with the concept of the atom, they often find it difficult to correctly apply scientific models of the structure of matter. For example, they tend to transfer properties of macroscopic objects to atoms and molecules (Albanese & Vicentini, 1997). They fail to recognize the emergent nature of many physical phenomena because they argue within the wrong ontological category (Chi, 2005). For instance, instead of attributing the temperature of an object to the average velocity of its molecules, they assume that the building blocks of matter also have a temperature.

To address this problem the presented design-based research project pursues two goals: (1) developing and evaluating a teaching and learning environment (TLE) on the particulate nature of matter that can be used in secondary education and (2) generating domain-specific instruction theories (Haagen-Schützenhöfer & Hopf, 2020). As a starting point for the development, *key ideas* about the particulate nature of matter have been formulated within the model of educational reconstruction (MER) (Kattmann *et al.*, 1996). Thereby, the key ideas are designed by taking knowledge about the students' conceptions (see e.g. Harrison & Treagust, 2006) and scientific content into account. The key ideas are then evaluated via teaching experiments regarding their utility for learning about the concept. Students' responses are subsequently analyzed using qualitative content analysis (Kuckartz, 2018). The results of the analysis then are used to re-design the key ideas. Following the cyclic character of design-based research, this procedure is repeated several times, promising a successive improvement of the TLE and especially the key ideas as well as new insights into students' thinking about the particulate nature of matter.

Review of Literature

When addressing the particulate nature of matter to students even the word "matter" is often misunderstood, as gases are not classified as matter but rather associated with the properties of energy forms (Lee *et al.*, 1993; Stavy, 1991). Students in secondary school know words like "atom" or "molecule" and can as well describe the relations between these two terms, which they see as the smallest portions of matter. Nevertheless, they attribute the same properties to atoms and molecules as to the substance they compose (Albanese & Vicentini, 1997). As an example, many students assume that the size of water molecules changes during phase transitions (Griffiths & Preston, 1992).

Furthermore, some students think that molecules are suspended in another substance and that there is always something between them (e.g. air). This might also be due to widespread depictions of the particulate nature of matter used in science education, showing particles drawn inside a continuous shape (Harrison & Treagust, 2006). Also, drawings in science textbooks regarding the spacing of particles in the three states of matter are often contrary to the scientifically accepted viewpoint (Treagust *et al.*, 2010). Whilst the correct ratio for the spacing between particles in solids, liquids, and gases being about 1:1:10 (de Vos & Verdonk, 1996) drawings in textbooks are usually more narrow. Therefore students assume that in solids the particles are in contact with each other, in liquids the particles are about one particle apart and particles in gases are about three to four particles apart (Treagust *et al.*, 2010).

Research Questions

In light of students conceptions about the particulate nature of matter that can be found in the literature, the following research question will be answered during the research project:

1. How can students' understanding of the relationships between macroscopic and submicroscopic levels of matter be improved?

In the course of answering the first research question, two further research questions will be tackled to design the teaching and learning environment:

2. What views on different arguments supporting the particulate nature of matter do students express during teaching experiments?
3. Do typographic representations promote scientifically appropriate ideas about the particulate nature of matter?

The second research question aims at finding guidelines for instruction, how the particulate nature of matter should be presented to students so that they might recognize it as a useful framework for explaining scientific phenomena. The third research question is derived from the relation between textbook representations and students' misconceptions about particles. To avoid any attributions of macroscopic phenomena to particles, an alternative type of representations derived from Wiener *et al.* (2015) is presented.

Research Design and Methods

Based on the key ideas about the particulate nature of matter a guideline for interviews according to the method of probing acceptance (Jung, 1992) has been developed. This method features a combination of a micro-teaching session and a one-on-one interview. Instead of just asking the students questions, the interviewer presents an explanation, intending to find instructional obstacles within the topic being presented. Therefore, after having heard the explanation of the key idea, the students shall first tell the interviewer if they find the idea sensible and plausible. After that, the students should paraphrase the idea. This will provide information about what part of the presented content appears most important to the students and if they implement scientific terminology into their explanation. If the students have difficulties, the interviewer tries to lead students into reconsidering the problem by asking further questions. To make sure that the students understood the key idea, the interviewer then gives them at least one task, to gain information about whether they draw on the presented ideas or not.

Preliminary Findings

So far 20 interviews have been conducted. The collected data has been evaluated using evaluative qualitative content analysis (Kuckartz, 2018). The analysis features a deductive coding system, based on the four particle models by Johnson (1998). In case of inaccurate fit, the coding system has been refined by an inductive approach. As an example, this has been the case when students have been asked if the human body is also composed of particles. Because some students have reacted showing negative emotions, while still accepting the idea of particles to some extent, the coding for this item had to be altered.

The first 20 interviews featured five different experiments as arguments for the applicability of the particulate nature of matter. By seeing the experiments and hearing the explanation of the interviewer students should be convinced to use the particulate nature of matter when explaining scientific phenomena. However, the data suggest that students have great difficulties connecting the particulate model with observations in the experiment. Furthermore, none of the five experiments seems to be particularly useful in convincing students of the particulate nature of matter.

Besides the hands-on experiments, a model experiment on the states of matter (Itakura, 2019) has also been presented to the students. Here, students' acceptance as well as their ability to paraphrase the explanation and answer follow-up questions was higher. Maybe the fact that they could actually "see" what is happening on the molecular level in the model experiment made it easier for them to understand.

Concerning the third research question, students were shown different depictions of the structure of matter. Typographic illustrations, that use the chemical formula as representation for molecules showed better acceptance than ball-shaped drawings of atoms and molecules that can be found in physics textbooks. Depictions showing a continuous structure of matter have been chosen only by a few students.

Because experiments did not prove to be convincing, further arguments supporting the particulate nature of matter (e.g. crystallization, Scanning Tunneling Microscope images) will be evaluated as the research project progresses.

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A Conceptual Framework for Digital Research Skills in Secondary Science Education

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Keywords: Science, Secondary Education, Digital Research Skills, Transition Gap.

Focus of the Study

The main aim of this study is 1) to provide a framework for the combination of DLS and RS, which we propose to label *Digital Research Skills* (DRS), and 2) to evaluate how proficient science university teachers judge their incoming students to be in these skills.

Review of Literature | Theoretical Background | Theoretical Framework

First-year university students have been reported to lack skills related to adapting, interpreting, and evaluating outcomes during data processing and working with statistics (Oakleaf & Owen, 2010). These results were mirrored in a study by Akuegwu and Uche (2019) reporting a low level of (general) RS in pre-university students: reading, presentation, communication and information-gathering skills were found to be adequate, whereas data analysis was found wanting. Other research has confirmed this problematic level of skills such as information-seeking and using ICT among students in secondary education (Julien & Barker, 2009; Smith *et al.*, 2013).

Despite the importance of DLS and RS for academic success (Oostdam *et al.*, 2007; Warschauer *et al.*, 2004), only a few scientific studies have addressed the development of these skills in secondary education and the way this affects the ensuing transition to science undergraduate education.

A formal combination of RS and DLS was not been encountered in this search, and little appears to be known about the assessment of the combination of these skills in secondary education. Due to the rapidly changing field, we have studied publications from the past ten years that were related to or assessed in secondary education.

In Table 1 (See next page), we have combined several leading frameworks for DLS with the RSD framework presented by Willison (2018) in order to arrive at a framework for DRS. When combining the frameworks, we looked at research skills in the RSD framework that highly correspond to DLS in the other (ICT) frameworks. Our DRS framework incorporating seven categories: 1) Browse, search and filter information; 2) Gather, measure and collect digital content/data; 3) Determine the accuracy and validity of sources/methods; 4) Structure, manage and protect content/data; 5) Analyse, transform and visualise content/data; 6) Write a research paper using digital tools, and 7) Share and present content/data.

Research Questions

Which digital research skills (DRS) show a gap between the final level of pre-university and the required entry level for science studies, as perceived by university teachers?
The three sub-questions are:

1. How can research skills and digital literacy skills be integrated in a usable combined framework for digital research skills (DRS)?

2. Which DRS do university teachers consider important for beginning science students?
3. What are university teachers' perceptions about first-year students' level of DRS?

Table 1. Matching of research skills and digital literacy skills to identify corresponding digital research skills (DRS).

Research skill (RSD)	Similar digital literacy skills in leading frameworks	Corresponding digital research skill
1. Embark and clarify	Browse, search and filter data, information and digital content (DigComp) Use advanced search techniques with digital and network tools and media resources (TEL)	1. Browse, search and filter information
2. Find and generate	Access information (ICILS) The ability to construct knowledge by nonlinear navigation (DL) Select digital and network tools and media resources (TEL) Use digital tools and resources (TEL)	2. Gather, measure and collect digital content/data
3. Evaluate and reflect	Evaluate information (ICILS, DigComp) The ability to consume information critically and sort out false and biased information (DL) Search media and digital resources on a community or world issue and evaluate the timeliness and accuracy of the information (TEL) Evaluate the credibility of the source (TEL) Justify choices based on the tools' efficiency and effectiveness for a given purpose (TEL)	3. Determine the accuracy and validity of sources/methods
4. Organise and manage	Manage information and digital content (ICILS, DigComp) Safety, privacy and security (ICILS, DigComp, TEL) Netiquette, copyright and licenses (DigComp) Knowledge about many different ICT tools (TEL) Responsible and ethical behaviour (TEL)	4. Structure, manage and protect content/data
5. Analyse and synthesise	Transform and create information (ICILS) Integrate and re-elaborate digital content (DigComp) Creatively use digital technology (DigComp) The ability to process and evaluate large volumes of information in real time (DL) Use digital tools to collect, analyse, and display data in order to design and conduct complicated investigations (TEL) Conduct a simulation of a system using a digital model (TEL)	5. Analyse, transform and visualise content/data
6. Communicate and apply	Develop digital content (DigComp) Manipulate pre-existing digital texts and formats (DL) The ability to create authentic, meaningful written and artwork (DL) Explain rationale for the design and justify conclusions based on observed patterns in the data (TEL)	6. Write a research paper using digital tools
6. Communicate and apply	Share and interact with information through digital technologies (ICILS, DigComp) Develop digital content (DigComp) The ability to communicate effectively in online communication platforms (DL)	7. Share and present content/data

RSD (Willison, 2018); ICILS (Fraillon *et al.*, 2013, 2014); DigComp (Carretero *et al.*, 2017; Ferrari, 2013; Vuorikari *et al.*, 2016); DL (Eshet-Alkalai, 2002); TEL (National Assesment Governing Board, 2018)

Research Design and Methods

In order the answer the second and the third sub-questions, we conducted an exploratory qualitative study to clarify what DRS are required at the start of higher science education in our country.

This qualitative study was based on semi-structured interviews with 15 academics who teach at the university level. The academics were professors, teachers, coordinators, program directors and education directors and were selected based on the following criteria: they teach first-year chemistry and/or physics students and supervise or teach these students when the students are during a research project. Out of a total of 30 candidates, 15 responded; the interviews were conducted on a voluntary basis. Participants provided written informed consent, which was repeated orally at the start of the interview. The academics were men and women in different age categories spread over eight theoretical and two technical universities in the country.

All recordings were transcribed and pseudonymised. Potentially interesting quotes from the participants were selected and coded using the categories in the DRS framework. Similar skills were grouped together per category. Each quote was also coded as reflecting either a positive or negative perception by the interviewee. We used the inductive approach of (Burnard *et al.*, 2008) and looked at how often a skill was mentioned per category. We organized the data in a bar chart, where the bars were divided into positive and negative quotes.

Quantitative data were obtained from the last two interview questions. The scales on the interviewees' ratings of importance or satisfaction with the degree to which their students have mastered digital skills in applications such as Word, Excel, and PowerPoint were averaged and organized in a diagram.

Duplicate coding was done on 50 of the 223 quotes; Cohen's kappa was found to be 0.88 for determining whether a quote was positive or negative and 0.81 for assigning the codes to the seven categories of the DRS framework, indicating good to near-perfect interrater reliability.

Preliminary Findings

During the interviews with professors, teachers, coordinators, program directors and education directors, 223 quotes with examples in the field of DRS were identified, in response to the second interview question. The most frequently mentioned examples belong to category 6: Write a research paper using digital tools (76 quotes with examples); 60 quotes with examples concerned category 5: Analyse, transform and visualise content/data and 41 quotes with examples concerned category 2: Gather, measure and collect digital content/data.

Quotes with examples such as being able to use search engines, assessing and selecting sources for reliability and transform data into a graph were mentioned by 13 of the 15 interviewees. Examples associated with writing a research paper were mentioned by all interviewees, included details such as using calculating functions, a functional type of chart with correct labelling of axes, display of measurement points and use of a caption.

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3.3 Mentor Group 3 | Windmolens | 3.3.4

Disclosure Decisions: Science and Engineering Instructors as Role Models with Concealable Stigmatized Identities

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Keywords: Biology, Tertiary Education, Role Models, Concealable Stigmatized Identity

Focus of the Study

University instructors serve as role models for their students and can impact students' choice to persist in the discipline based on whether the instructor has identities similar to the student – in other words, *you have to see it to be it*. Race and gender identities tend to be outwardly apparent, and it is especially important for students of marginalized identities (e.g., Black, Hispanic) to have role models with the same identities (Rask & Bailey, 2002; Shin *et al.*, 2016). Concealable stigmatized identities (CSIs) are identities that can be kept hidden and carry negative stereotypes depending on the culture of a particular context; common examples in the United States are low socioeconomic status, LGBTQ+ identities, addiction, and mental health conditions. While national organizations such as the U.S. National Science Foundation collect gender, racial, and disability demographics, little is known about the extent to which professors have CSIs. Even less is known about what factors influence whether instructors reveal CSIs to their students.

There are many calls to increase retention of science and engineering undergraduates into graduate and professional positions in the United States. Student-instructor relationships are one of the most effective means of promoting student persistence, thus it is imperative to understand the diversity that exists within the professoriate outside of the standard suite of demographic characteristics. This study seeks to understand the diversity of concealable and apparent identities that professors across U.S. higher-education institutions hold and explore how instructors navigate the decision to disclose or withhold those identities to their undergraduates. This study will be the first to quantify a wide array of CSIs held by instructors which will inform how many professors are role models for their students by virtue of CSIs and apparent identities, and whether and how professors share these identities.

Review of Literature

Instructors, whether knowingly or not, are role models to students in their discipline. Students often perceive instructors as role models based on identities that they share, such as gender and race (Cotner *et al.*, 2011; Rainey *et al.*, 2018). Gender and race tend to be visible identities that students know upon first introduction whether they share these identities with an instructor. For identities that are not conspicuous (i.e., are concealable), such as socioeconomic status or religion, the instructor must disclose the identity in order for students to know that the instructor identifies in a particular way. Concealable stigmatized identities (CSIs) can be kept hidden and carry negative stereotypes (Quinn, 2006). Therefore, individuals with CSIs must decide whether to reveal their identity to others. Science and engineering are considered "chilly" environments that emphasize keeping personal matters out of the classroom (Seymour & Hunter, 2019), so instructors may be hesitant to reveal their CSIs in academic contexts, including undergraduate classrooms.

There have increasingly been calls in the United States to increase retention amongst science, technology, engineering, and mathematics (STEM) undergraduates (Olson & Riordan, 2012). Enhancing the student-instructor relationships increases student sense of belonging in STEM, which is a major predictor of retention (Fink *et al.*, 2020). Instructor self-disclosure, or the sharing of appropriate personal information, makes instructors more relatable to students and increases how connected students feel to instructors (Myers *et al.*, 2009). Revealing CSIs may be particularly effective instances of instructor self-disclosure and disproportionately affect undergraduates, as these identities are not commonly visible in STEM and are marginalized. For example, if undergraduates with depression learn that one of their scientist role models also identifies as having depression, they may be more likely to see STEM careers as a viable possibility (Cooper *et al.*, 2020). However, the stigma associated with CSIs decreases instructors' willingness to reveal these identities (Cooper *et al.*, 2019). Thus, examining instructors' patterns and decisions of disclosing CSIs within the context of their undergraduate classrooms will elucidate types of instructor self-disclosure that are most impactful for students and whether being a role model for students with the same CSI affects students' intent to persist in science and engineering.

This study will be the first to survey university instructors about a diversity of CSIs (e.g., religion, childhood socioeconomic status, sexual orientation) systematically at a large-scale across multiple institutions. Thus, it will not only elucidate the frequency of CSIs across the professoriate, but it will provide a critical foundation for future research on a wide variety of identities. Importantly, future interview studies with university instructors that participate in the survey will allow for a deeper understanding of individuals' decisions of whether and when to reveal their CSIs in the context of the undergraduate courses that they teach and how they navigate academic science and engineering with a CSI. Together with the initial survey study, these interviews will further uncover the decision-making process preceding instructor self-disclosure and the benefits or potential consequences that instructors have experienced as a result of revealing a CSI.

Research Questions

1. To what extent do science and engineering faculty and instructors hold concealable identities?
2. To what extent do they consider those identities stigmatized in academic science and engineering?
3. Do they reveal those identities during their undergraduate courses?
4. What factors influence their decisions to reveal or conceal such identities?

Research Design and Methods

Survey overview

For the first phase of the study, we conducted a national survey of over 50,000 faculty and instructors in science (i.e., biology, chemistry, geosciences, and physics) and engineering from very high research (R1) institutions across the United States. We began by surveying instructors at R1s because roughly a third of U.S. undergraduate students attend these schools. We asked a suite of demographic questions, including 15 concealable stigmatized identities such as history of mental health conditions, childhood socioeconomic status, and religious affiliation. Participants then indicated if they revealed these identities to students formally in their undergraduate courses, during informal settings such as office hours, or if they never share these identities with undergraduates. We also surveyed participants about the reasons they choose to reveal or conceal their concealable identities. Of the individuals contacted, approximately 2,150 have already participated in our survey.

For the second portion of the study, we will contact an additional 45,000 faculty and instructors in science (i.e., biology, chemistry, geosciences, physics) and engineering from masters-granting institutions, primarily undergraduate institutions, and community colleges. In the second portion of the study, we expect to have approximately 3,000 participants.

Analyses

We will first report the overall representation of each group within our sample. Using logistic regression, we will quantify whether particular demographic characteristics or appointment type (e.g., tenure-track) predict an individual's decision to reveal or conceal an identity. We will report which reasons were most commonly reported for why individuals chose to reveal or conceal their identities and assess whether there are demographic differences in these reasons using logistic regression. We predict that instructors are more likely to reveal identities that they perceive as less stigmatized.

Analysis of the data from instructors at R1s as well as at masters-granting institutions, primarily undergraduate institutions, and community colleges will be conducted as described above. Additionally, we will collate the responses and model the effect of institution type on instructors' decisions to reveal their CSIs.

Preliminary Findings

To date, the data have been collected and analyses are in progress for the R1 dataset. Initial findings include the demographic breakdown of participants and the concealable stigmatized identities they report (Figure 1). Participants are most commonly men, white, non-LGBTQ+ (i.e., straight or heterosexual), not religious, and have no history of depression, anxiety, or addiction. Further, they most commonly grew up in a middle-income household and are not first-generation college students. Additional analyses into the intersections of identities (i.e., race, gender, and childhood socioeconomic status/sexual orientation/religion) are forthcoming and will be underway at the time of the summer school. Data collection for the second phase of the project is scheduled to occur over the summer and preliminary data may be available at the time of the summer school.

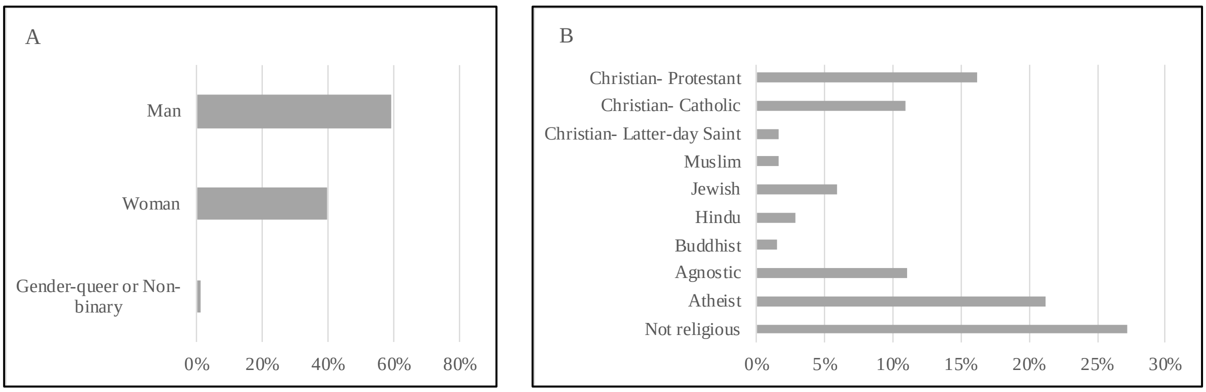

Figure 1. Demographic results of an example of (A) a conspicuous identity, gender, and (B) a concealable identity, religion for instructors in science and engineering at R1 institutions.

As the preliminary results are descriptive in nature, many of our research questions are yet unanswered. However, the preliminary results are exciting and we can begin to see the potential for instructors to be role models for the increasing number of STEM undergraduates in the

United States, but particularly those from marginalized backgrounds or who also hold these concealable stigmatized identities.

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Assessment of Chemistry Teacher Student's Diagnostic Competencies in the Simulated Chemistry Classroom (SiCC)

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Keywords: Chemistry, Secondary Education, Simulated Classroom, Diagnostic Competencies

Focus of the Study

Accurately assessing students' performances and their individual learning progressions is one of the most important tasks and challenges of teachers' profession (Kaiser & Möller 2017, p. 56). Based on these assessments, teachers design their instruction (McElvany *et al.* 2009, p. 223). Accordingly, it is reasonable to assume, that the ability to assess students' performances accurately has a positive impact on students' learning progressions (Möller *et al.* 2016, p. 16). Therefore, it is important to investigate teachers' as well as teacher students' diagnostic competencies.

Theoretical Background

In empirical educational research, diagnostic competencies are measured by determining the level of agreement between a teacher's judgement of a specific characteristic of a student's performance and the student's test performance (Schrader & Praetorius 2018, p. 93). This basic definition of judgement accuracy as a manifestation of diagnostic competencies forms the core of the *Heuristic model of teachers' judgment accuracy*" by Südkamp, Kaiser & Möller (2012, p. 756). The model describes factors which potentially affect a teacher's judgement, namely the individual teacher characterists (e.g. their cognitive abilities) and the judgment characteristics (e.g. the ranking scale). The model further describes variables, which potentially affect a student's test performance, strictly speaking the student charactristics (e.g. their level of subject specific competencies) and the test characteristics (e.g. the test's domain specificy). All variables mentioned finally affect the teacher judgement accuracy.

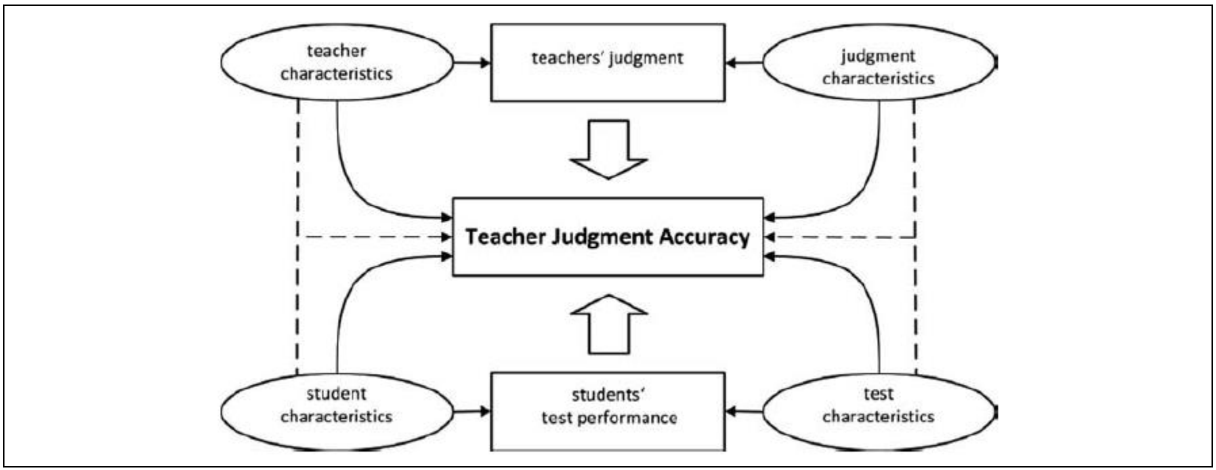

Figure 1. Heuristic model of teacher's judgement accuracy (Südkamp, Kaiser & Möller 2012, p. 756).

According to Schrader (1989, pp. 86-89), the accuracy of a teacher's judgement can be measured in terms of three statistical components. These components are: the *rank component*, the *level component* and the *differentiation component*. The *rank component* describes the agreement (strictly speaking the correlation) between the estimated ranking of students' performances and the actual ranking of students' performances. It is also of interest how accurately teachers assess the performance level of a class or of an individual student. The assessment of the performance level is described by means of the *level component*. Statistically, it describes the difference between the estimated performance level of a class and the actual performance level of a class. The third component mentioned in this field is the so called *differentiation component*, which indicates the ratio of the estimated dispersion of the student's performances to the actual dispersion of the student's performances. (Südkamp & Praetorius 2017, pp. 21-22).

Schrader (1989, p. 57) also describes two kinds of judgements that differ in terms of the characteristics being assessed. According to Schrader (1989) the *person-related*, the *task-related* are to be considered. *Person-related judgements* describe the assessments of an individual student's performance, while *task-related judgements* refer to the assessments of the difficulty of individual tasks or questions.

Research Questions

1. To what extent are student teachers of chemistry able to accurately assess students' performances when they have to make *person-related* and *task-related* judgements and assess the quality of students' answers?
2. To what degree are there interdependencies between prospective teachers' judgment accuracies regarding *person-based* and *task-based* assessments as well as judgments of response quality?
3. To what extent is it possible to enhance the development of diagnostic competencies of prospective chemistry teachers?

Research Design and Methods

In order to investigate our research questions, we adapted the Simulated Classroom (*SiC*) in order to create the Simulated Chemistry Classroom (*SiCC;* see Bolte *et al.* 2012; 2021), a special version of the Simulated Classroom (*SiC*) focussing on the school subject chemistry grades 7 and 8. In the *SiCC* the participants communicate with 12 simulated students by asking questions or giving tasks. Depending on previously set motivational parameters, several simulated students raise their hands. When being called upon, a simulated student responds accordingly to their previously set performance parameters. After a certain amount of time – in our case after 20 minutes – the participants judge the students' performances. Based on the participants' judgements and the students' performance parameters, the accuracy of the participants' judgments is determined.

We designed a list of tasks and questions suitable for grades 7 and 8. The questions and tasks reflect three different levels of difficulty (easy, moderate and difficult tasks). In contrast to pevious studies (see Bolte 2012; 2021) we formulated student answers that are either *"correct"*, *"only partially correct or incomplete"* or *"incorrect"* for each task and question. We chose this approach because, in our experience, student statements are rarely completely correct or incorrect, but rather partially correct or incomplete. In order to stimulate the participants of our study and to offer them an overview of the tasks and questions they could use in the *SiCC*, we asked them to review the list of questions and tasks used in the *SiCC* and to assess the difficulty level of each task or question before they start the first run of the simulated chemistry lesson.

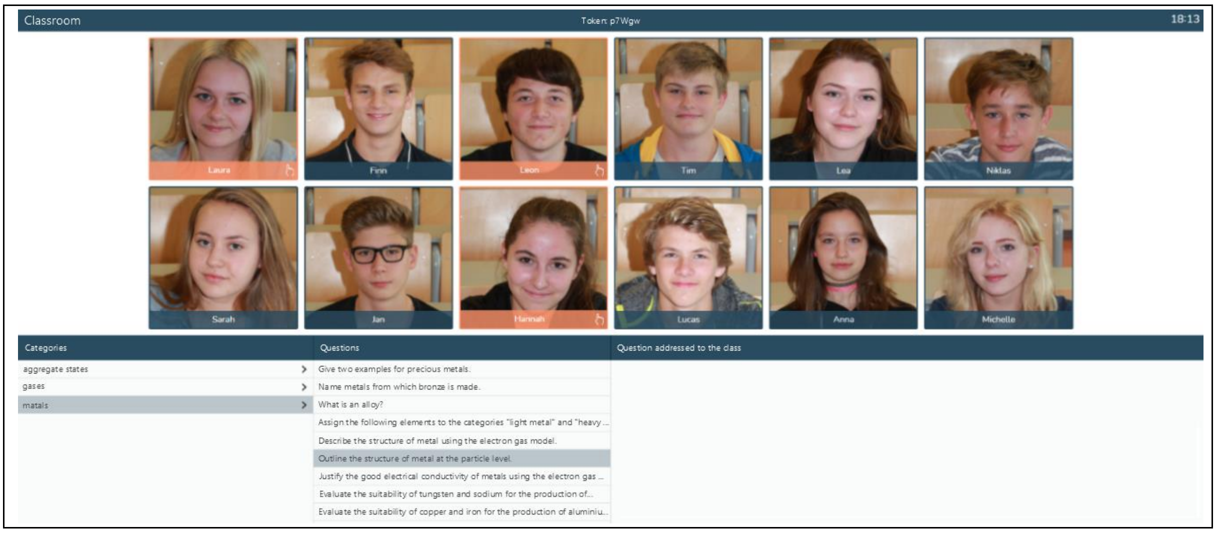

Figure 2. User interface of the current SiCC version (translated from German).

The simulated class consists of six male students and six female students of Caucasian appearance with common names to prevent bias in measurement results due to minority effects based on sex or ethnicity (see Kaiser, Südkamp & Möller 2017). We divided the simulated students into three performance groups (high, moderate and low achievers). Each performance group contains two boys and two girls. Depending on their performance group we assigned nine performance parameters to each student. The performance parameters of the three performance groups are displayed in Table 1 below.

Table 1. Distribution of the students' performance parameters for different task difficulties (left number indicates the probability of a "correct" answer; middle number indicates the probability of an answer that is "only partially correct or incomplete"; right number indicates the probability of an "incorrect" answer).

	Easy Task	Moderate Task	Difficult Task
High Achievers	100/0/0	75/15/10	50/30/20
Moderate Achievers	75/15/10	50/30/20	25/35/40
Low Achievers	50/30/20	25/35/40	0/0/100

We set the motivational parameter of each student to 0.5, meaning that they will raise their hands 50% of the times the participant asks questions or gives tasks. Being aware of the fact that this most certainly is not the case in a real class, we have chosen this approach to counteract measurement errors based on the interdependence of the assessments of performance and motivation (see Kaiser *et al.* 2013).

In our study the participants conduct a chemistry class discussion twice; with each class discussion (run) taking twenty minutes. In the two runs the participants use the same list of tasks and questions and teach the same simulated students. At the end of each run, the participants estimate the percentage of each simulated student's correct answers in general (regardless of the tasks' difficulty). The participants also rate the percentages of correct answers for each of the three different difficulty levels. The participants' judgement accuracy is determined according to the judgement components regarding the students' performance parameters.

Preliminary Findings

A total of 23 chemistry teacher students participated in our first study. The results of this study are listed in Table 2 below.

Table 2. Judgement components for the SiCC.

	Run	All Tasks	Easy Tasks	Moderately Challenging Tasks	Difficult Tasks
Rank Component	1st	0.24	0.21	0.22	0.21
	2nd	0.52	0.41	0.42	0.42
Level Component	1st	0.20	0.07	0.18	0.33
	2nd	0.18	0.03	0.16	0.29
Differentiation Component	1st	0.82	0.65	0.88	1.07
	2nd	1.02	1.15	1.38	1.31

According to the *rank component scores* (Table 2), the participants are limited in their ability to rank students' performances when considering all task difficulties. However, the accuracy of their performance ranking increased substantially during the second run. This effect can either be explained by the fact that the participants gathered more information on the students after the second run or by possible training effects (see Bolte *et al.* 2021). The *level component* scores for all tasks indicates a substantial overestimation of the performance level after the first and second run. During the second run, the overestimation is slightly lower, but still substantial. In accordance to the *differentiation component results* for all tasks, the participants underestimated the performances' dispersion during the first run. During the second run, the participants' judgement of the performances' dispersion improved substantially to the point of an almost optimal score. In accordance to the *rank component* considering different task difficulties, the participants' ability to rank the simulated students' performances does not depend on the difficulty of the tasks and questions selected to test the simulated students. The *level components for different task difficulties,* however, indicate that the overestimation of the performance level increases with the tasks' difficulty. Regarding the scores of the *differentiation component* for different task difficulties, the picture is less consistent. Regardless of the difficulties taken into account, the participants' judgement of the performances' dispersion takes on higher scores after the 2nd run. Whilst this indicates an increase of the judgement's accuracy regarding easy tasks, it also indicates a decrease of the participants' judgement accuracy regarding moderately challenging and difficult tasks.

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3.3 Mentor Group 3 | Windmolens | 3.3.6

Teacher Needs-based Science Teacher Professional Development Model that Promotes Changes in Teacher Classroom Practice

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Keywords: Science Teacher Professional Development, Professional Development Needs, Implementation

Focus of the Study

Since 2020 Latvia like other European nations is experiencing a science curriculum change that features a focus on conceptual understanding (CU) of science subject concepts, scientific reasoning, construction of explanations and arguing from evidence as student learning outcomes. Analysis of National level assessment data highlight that students struggle to solve problems that demand the higher-order cognitive skills mentioned above (Pestovs & Namsone, 2019). Also, science teacher classroom observations highlight that there are only some lessons where teachers deliberately and meaningfully guide students toward CU (Dudareva, Namsone, Butkevica, & Cakane, 2019). The targets of the reform are ambitious, teachers are seen as crucial executants of educational policy and science teacher professional development (STPD) is seen as a key mechanism for the implementation of the educational reform.

In recent years more and more reports about effective STPD programs are published, still, science teacher cognitive and motivational characteristics are rarely considered by teacher educators and majority of the teacher professional development (TPD) programs inherit a "one-size fits all" approach. Also, programs developed according to the principles of effective TPD doesn't always lead to changes in teachers practice and changes in student outcomes. The importance of context and implementation process of a theoretically sound professional development (PD) initiative are two aspects that can either catalyse or inhibit these ultimate changes (Patfield, Gore, & Harris, 2021).

The present research is targeted to tackle both problems mentioned above and is focused to find solutions for STPD that can change teacher classroom practice in order to promote student CU.

Theoretical Background

Student's Conceptual Understanding

The goal of STPD developed in this research are changes in teacher classroom practice that can positively enhance student conceptual understanding. Concepts and principles are the basic building blocks of scientific knowledge and understanding of a concept is precondition for making complex inferences or accomplishing any scientific work with it (Mi, Lu, & Bi, 2020). Therefore, it is decisive for students to attain CU about the core ideas of science subjects and build this understanding coherently. Many scholars agree that students CU can be elaborated when science lesson builds on the ideas that student bring to lessons and trough cognitive conflict changes these ideas to scientific ones. Modelling, scientific argumentation, scientific reasoning, construction of explanations are some of the most powerful classroom practices that can be both promote cognitive conflict and help to assess student CU (Osborne & Dillon, 2010). In majority of cases, these practices are novel or partly understandable to science teachers and effective TPD is seen as a pathway to meaningfully incorporate these practices in science teacher everyday practice. Still, questions remain – what the most effective way is how such STPD should be conducted (Hugerat, Mamlok-Naaman, Eilks, & Hofstein, 2015).

Teacher Professional Development

The object of this research is STPD, which in context of this research is seen as "activities explicitly designed for and provided to educators or certified educational professionals with a focus on enhancing their own and their students' knowledge, skills, and attitudes" (Guskey, 2003). This research follows the premises that adults learn by transforming their frames of reference by changes in their points of view and habits of mind (Mezirow, 1997) and TPD can be described by the interconnected model of teacher professional growth (Clarke & Hollingsworth, 2002), which states that changes in teacher personal and external domains are interconnected and can be mediated by either application or reflection. The research follows the principles of effective TPD proposed by Darling-Hammond (2017) and sees content focus; active learning; collaboration; models of effective practice; coaching and expert support; feedback and reflection; sustained duration as criteria that characterize the quality of STPD interventions. Still the outcomes of STPD aren't dependent only from the quality of the intervention. The quality of the implementation of TPD should also be considered. The eight implementation outcomes described by Proctor *et al.* (2011) can be used as criteria to evaluate the quality of STPD intervention.

Teacher Professional Development Needs

The research is designed around the idea that science teachers differ by their quality, knowledge and motivation, and various needs can and should be linked by various TPD interventions (Zhang *et al.*, 2017). In the last two decades research on TPD has focused on determination of TPD needs via teacher self-reflection and various external instruments (Owens, Sadler, Christopher, Murakami, & Tsai, 2018). Still, there is an avenue for research that links various TPD needs with appropriate solutions (Bae, Hayes, & DeBusk-Lane, 2020).

Research Questions

1. How to identify and prioritize Latvian STPD needs to promote student CU?
2. How TPD model that can be used to promote changes in science teacher classroom practices based on TPD needs can be designed?
3. How to develop and adapt materials that support changes in science teacher classroom practice leading to student CU.

Research Design and Methods

The research is designed according to design-based research methodology developed by Sandoval (Sandoval, 2014) and include three iterative research cycles (see Figure 1).

To evaluate teacher learning and teacher, school leader and teacher educator roles in the implementation of the model data will be obtained through mixed-methods approach (see Table 1).

Table 1. Data collection methods.

Source of data:		Teachers	School leaders	Teacher educators
Data collection methods:	Qualitative	Semi-structured interviews, Focus group discussions		
	Quantitative	Knowledge tests, Lesson observations, Surveys	Surveys	Surveys

Qualitative and quantitative data will be encoded, compiled and processed to find possible linkages using appropriate software (i.e., SPSS; NVIVO).

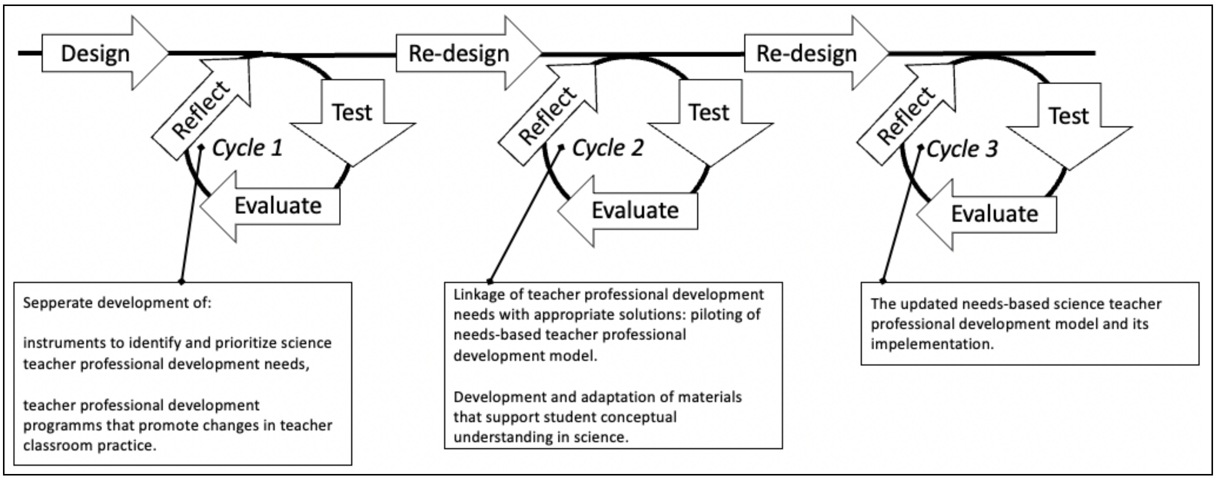

Figure 1. Research design.

Preliminary Findings

First Design-based Research Cycle

Selected categories and criteria (see Table 2) that characterize teacher classroom practices to promote student CU have been chosen from the Framework of Teacher Performance Assessment to Support Teaching 21st Century Skills (Bērtule, Dudareva, Namsone, Čakāne, & Butkēviča, 2019).

Table 2. Selected categories and criteria from the framework developed by Bērtule *et al.* (2019).

Categories	Planning	Instruction
	Criteria	**Criteria**
A Student cognitive activation (SCA)	2.1 Tasks for cognitive activation	2.2 Classroom discourse
A Metacognitive strategies (MET		1.2 Promotion of metacognitive strategies
B Instruction (INSTR)	5.1 Instructional design	5.2 Classroom management
B Curriculum representation (CR)	6.1 Curriculum representation	

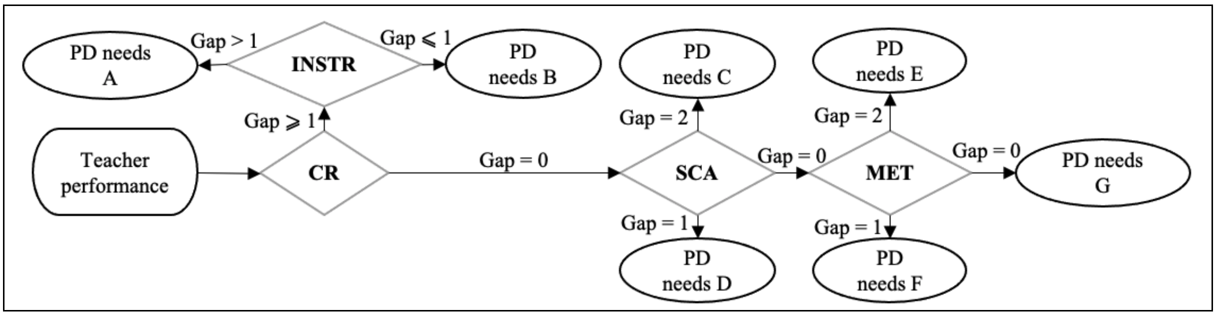

Figure 2. Algorithm for prioritization of STEM teacher PD needs.

An algorithm to identify and prioritize STPD needs to promote CU has been developed (see Figure 2). The algorithm prioritizes the selected categories trough comparison of the observed teacher classroom performance with the needed performance level in each category to judge, whether there is a performance gap. Teachers with similar sets of performance gaps are seen as teachers with similar TPD needs.

The algorithm has been used to identify six science teacher sub-groups with various PD needs. For example, PD needs A were identified for two Science teachers. For them the first PD priority is to reach the needed performance in instruction, then to reach the needed performance in criteria curriculum representation.

A TPD model that promotes change in classroom practice has been developed and tested in two urban secondary schools (25 teachers collaborated in 9 small groups).

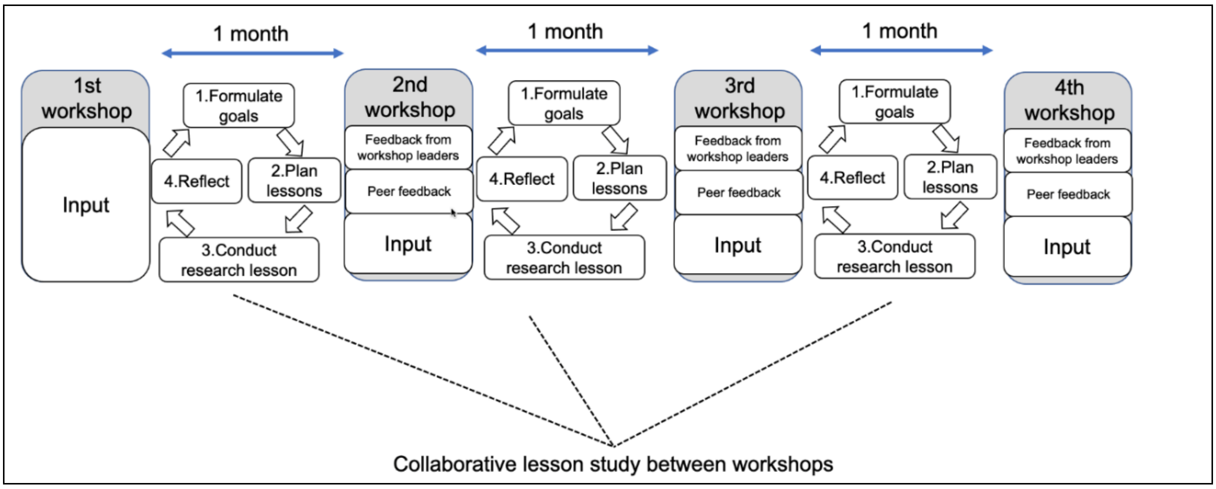

Figure 3. TPD model to promote change in classroom practice.

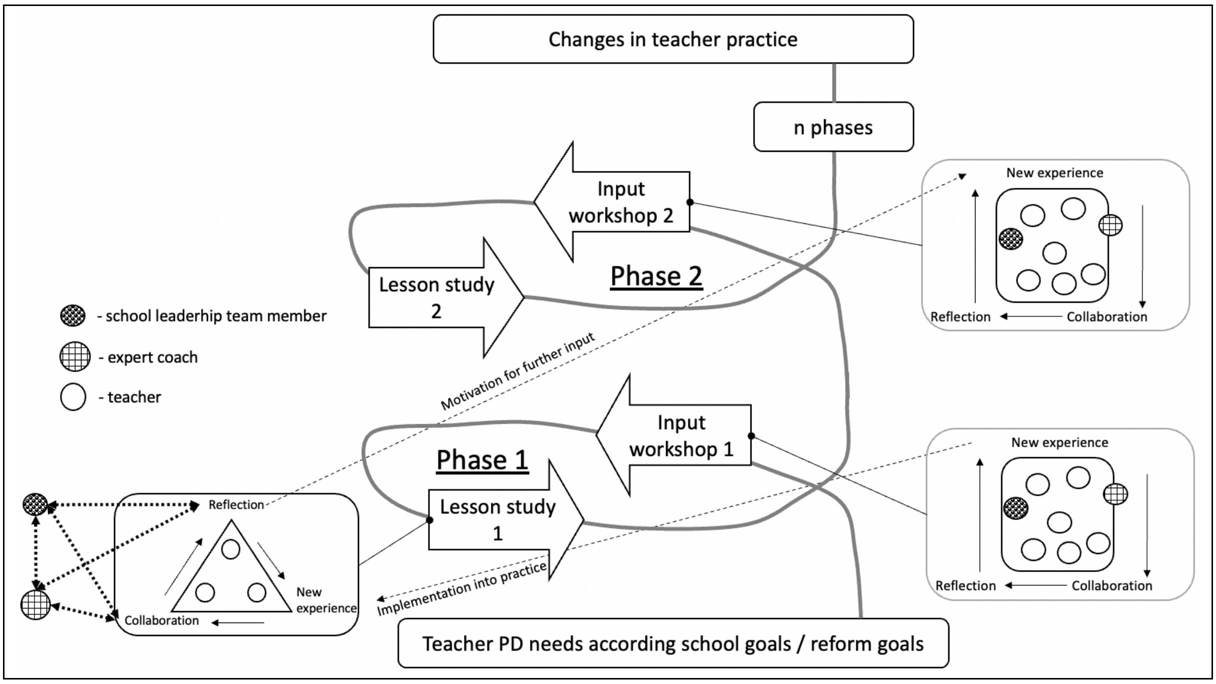

Figure 4. Updated TPD model.

The TPD model (see Figure 3) to promote change in classroom practice was designed according to principles of effective TPD. The model combines input workshops, that can be characterized by active participant learning, with collaborative lesson studies, to implement the obtained knowledge, between them. Such approach was chosen based on previous observations that throughout lesson studies teachers do their best in the planning and leading of the lessons. The results showed that not all teachers rapidly changed their practice (observed in participant lesson plans) throughout the PD. School leader interviews highlighted that changes in practice were observed between upper-secondary school teachers who had reached the necessary level in curriculum representation and classroom instruction. Teachers and teacher educators highlighted that throughout the implementation of the PD model school leaders should be more involved and proactive.

Second Design-based Research Cycle

The conclusions the first research cycle and other background parameters were considered to develop an updated TPD model to promote change in teacher practice (see Figure 4).

The algorithm to identify and prioritize TPD needs developed in first research cycle will be developed further and will include teacher knowledge test results, and perception questionnaire data. The updated model also places school leaders, teacher educators and teachers as stakeholders responsible for qualitative deployment and implementation of the model. From February 2022, 25 science subject teachers, 8 school leaders and 4 teacher educators will pilot the updated model.

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3.3 Mentor Group 3 | Windmolens | 3.3.7

How do Student Attitudes and Social Norms Influence Physics Students' Behaviour and Authenticity?

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Keywords: Physics, Tertiary Education, Belonging, Identity, Behaviour

Focus of the Study

Social norms within physics are currently an under-researched area, despite multiple studies citing the detrimental effect of physics stereotypes. Identifying these social norms is important as theory suggests that they are significant in behavioural decisions. Students in higher education who are unable to meet the expected social norms therefore, are at risk of changing their behaviour in order to fit in, or choosing to opt out. This study will investigate what social norms are present in a university physics department and explore how these social norms affect student behaviour and authenticity.

Review of Literature

Sense of belonging and physics identity have risen in prominence within the field of physics education over recent years (Odden, 2020). SOB affects students' motivation, achievement, and wellbeing within higher education (Freeman et al., 2007; Kuh et al., 2011) and within the domain of physics, SOB is as a dominant factor in continuation rates, even when constructs such as self-efficacy are controlled for (Lewis et al., 2017). Importantly, multiple studies suggest that the influence of SOB is stronger for students later in their degree course (Hazari et al., 2020; Lewis et al., 2017), implying that SOB becomes more important as students interact more with their physics community. In Hazari's work (2010), a significant covariance relationship was also found between SOB and both recognition and performance/competence, indicating that SOB varies with changing levels of recognition and competency. Again, this relationship differed over time, with the relationship between recognition and identity being higher for undergraduates, signalling a greater reliance on the external environment in forming their identity.

To fully understand how recognition affects physics identity and SOB, a greater definition of recognition is needed. Recognition in part can be thought of as how much an individual displays group characteristics and is therefore identified as being part of that group. Whilst there is little research on the specific characteristics associated with being a physicist, within STEM more broadly, research shows that scientists are associated with more 'negative traits' than their humanities peers (Kessels et al., 2006; Nosek et al., 2002; Nosek and Smyth, 2011; Steffens and Jelenec, 2011). Scientists are associated with being less attractive, more socially awkward, less creative, and less emotionally apt than non-scientists; conversely scientists are associated with a higher intelligence and motivation than non-science contemporaries. Research also shows that both men and women have an association of STEM with masculine.

Whilst research can and has found the existence of implicit stereotyping and bias within physics, less has been done on the subjective social norms of physics. Social norms can be defined in variety of ways, but this definition by Heise and Manji (2016) serves as a useful summary: norms are “. . . a social construct. It exists as a collectively shared belief about what others do (what is typical) and what is expected of what others do within the group (what is appropriate). Social norms are generally maintained by social approval and/or disapproval”. Ultimately this leads to individuals holding attitudes towards behaviours; within physics higher education it leads to some behaviours being viewed as more positive (e.g. reading beyond the course requirement) and others viewed more negatively (e.g. skipping classes).

The Theory of Planned Behaviour (TPB) as a framework links these affective attitudes with the environment (subjective norms) and perceived behavioural control to explain behavioural attitudes. It is impossible for any behaviour model to capture all factors which influence behaviour and so the TPB framework should not be seen as a predictive tool. Rather, it can be used in an applied sense, as it has been used on student retention (Dewberry and Jackson, 2018) and student enrolment (Ingram et al., 2000). From my literature review I am not aware of any physics education research that uses a TPB framework in its entirety, or as a modified version. However, the field of physics education research is limited and therefore I believe the use of such a framework will be a novel and valuable addition in understanding student behaviour.

Research Questions

1. What behaviours do staff and students value in a physics student?
2. What do both groups perceive the others value in a physics student?
3. How do these perceptions influence student behaviour and authenticity when becoming a physicist?

Research Design and Methods

The study will be conducted in two broad strands, part 1 (quantitative questionnaires) and 2 (qualitative focus groups), with part 1 being split further into 1a (students) and 1b (staff). The decision to use three different points of collection is to allow for different depths and breadths of questioning. In line with a TPB approach, this study will identity the behavioural attitudes and the social norms that students have in occupying certain behaviours. Part 1a and b will measure behavioural attitudes by asking “what skills and behaviours do you think are valuable in a physics student?”. It also will collect data on perceived norms by asking what students and staff perceive other groups such as peers/students/staff to value.

Part 1a will additionally collect data on students’ current behaviours and behavioural authenticity. Whilst this is not directly related to a TPB approach, measurement of authenticity is deemed important to complement the findings on student behaviour. Part 1b will additionally ask members of staff to describe the observed ways in which students can demonstrate the valued skills and behaviours. For example, “Please describe the ways in which a student may demonstrate “being creative”. This is to completement simple Likert responses and identify any divergence in staff perceptions of behaviours. Finally, part 1a will collect demographic information which will allow internal analysis of student data.

The design of the questionnaires have utilised recommendations from the original TPB (Ajzen, 2006) and have been influenced by the design of other TPB approach studies. For part 1a the sample will be students embarking on their first year of UG physics study. This survey will be administered a total of 6 times to cover a student’s entire time at university, therefore capturing longitudinal information on how these attitudes, perceived social norms, identity, and authenticity change. For 1b there will only be one point of collection as it is assumed that staff views will not change significantly over the course.

Based on analysis of part 1, students from targeted subgroups will be asked to join a 1-hour focus group(s) for part 2 of the study. The subgroup selection criteria are currently undetermined and will be chosen as a result of both the analysis of the interview data (part 1), and from secondary analysis of data from the wider research group findings. The focus group will probe further into findings from part 1, to gain a greater understanding to the perceived social norms within the physics department.

Preliminary Findings

At this point the first round of data collection has occurred for 1a (students) and all data has been collected for 1b (staff). Initial data analysis shows that students value behaviours in a very similar way, with no statistically significant differences between gender, ethnicity, fee status or previous schooling. When comparing with staff valued behaviours, five of the twenty items showed a statistically significant variation (see Figure 1). An important finding is that both students and staff alike have rated 'team-work' as being more valuable than 'good communication skills' or 'cross-cultural awareness' despite the skills being seemingly very similar. Upcoming focus groups will be used to pick at this finding to gain more understanding as to why particular skills and behaviours have been valued in the way that they have.

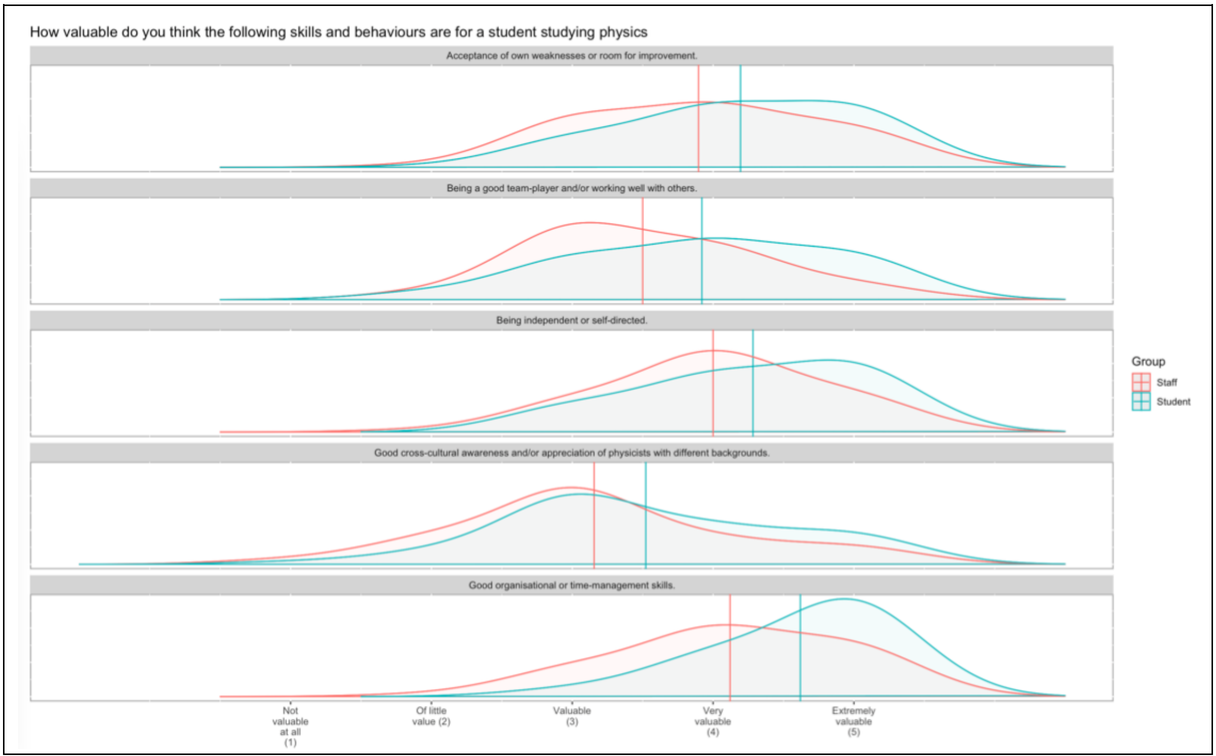

Figure 1. Distribution of staff and students' responses on five questionnaire items which showed a statistically significant difference in variation.

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3.4 Mentor Group 4 | Weilanden | 3.4.1

Filipino Americans in the US, Identities, and Science

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Keywords: Science, Secondary Education, Science Identity, Physics Identity, Case Study

Focus of the Study

Filipino Americans (FilAms) occupy a unique position in the United States' (US) racial structure because of the Philippines' legacy of colonialism under Spain and the US. The Filipino mindset of colonial mentality, which is an internalized assimilation into Western values results in an uncritical adoration of anything Western (Constantino, 1978). FilAms, as part of the Asian American (AsAm) diaspora are positioned as "honorary whites" (Bonilla-Silva, 2006) who self-classify into a higher stratum. However, FilAm students experience severe racial discrimination including being "minoritized" in predominantly white universities and experiencing economic hardships due to occupational downgrading (Ocampo, 2016).

With this study, I hope to explore the science experiences of a FilAm student and add to the body of literature on the racialization of AsAms in science (Chen & Buell, 2018). Past scholarship describes using AsAms as a wedge to legitimize or denigrate the experiences of other communities of color (Iftikar & Museus, 2018). Critical scholars debunked the model minority myth which stereotypes AsAms as innately successful in science and well educated (Shah, 2019). This myth cloaks the diverse pan-Asian community rendering their varying experiences invisible. The invisibility of FilAm students undergirds the research problem that I want to address with this study: the underrepresentation of FilAms in science and the lack of data and scholarship on the science experiences of FilAms.

Theoretical Framework

This study uses various identity frameworks to make sense of experiences. Social identity theory postulates that the membership of an individual within a social group helps form a social identity. By engaging in a social comparison with others, individuals develop "in-group" classifications for others who are similar and "out group" classifications for others who are different (Stets & Burke, 2000). By comparing and finding similarities with people in the "in-group," membership within a group becomes more prominent.

Learning is a process that involves identity development and skill acquisition within a community of practice (Lave, 1991). How individuals learn while engaging in activities within the community and the identities these engender are shaped by what the community demands, celebrates, and marginalizes. That identity development and skill acquisition are part of the same process is the basis for the Content Learning and Identity Construction (CLIC) framework developed by Varelas *et al.* (2012). CLIC posits that learning involves the simultaneous development of disciplinary identity, racial identity, and academic identity. When applied to FilAm students, teachers have to develop meaningful ways for students to see themselves as part of the science community at the same time that they develop the necessary tools, discourse, and norms within science.

Identities-in-practice are created from meshing the "person" and "society," and result in formation/reformation of social practices (Holland *et al.*, 1998). Thus, identities-in-practice are a person's ways of being while engaging in social practices, and people are in constant authorship of these identities. Contextualizing identities-in-practice for FilAms requires unpacking figured worlds and positional identities.

In everyday life, individuals are always "figuring" resulting in an interpreted, "figured world." Figuring is "thinking," which foregrounds one's interpretation of the world and the assigning of significance to some things while not others. Figured worlds are socially and culturally constructed and can be used as imaginary guideposts to categorize and assign meaning to actions. Positional identities are shaped by day-to-day interactions that involve power relations between individuals (Holland *et al.*, 1998). Carlone & Johnson (2007) highlighted the recognition by others in developing a science identity. That some women in their study developed disrupted science identities because they were recognized differently speaks to the power relations between structures like gender, race, and ethnicity that positioned these women in a different science category than other more successful scientists.

The separation between figurative and positional identities is blurry because they overlap in many ways. For example, linguistic choice is a result of one's figuring while shaping one's positional identity because languages, genres, and speaking styles have "social value." The figuring and the assignment of what is valued or not results in a social position. Furthermore, figurative identities evoke stories while positional identities evoke hierarchy (Holland, 1998). Within the FilAm community, doctors and engineers tend to have more social capital. Social capital is the aggregation of resources due to membership in institutions, which imbues a person with "credentials" that can be used in society (Bourdieu, 1986). This higher positioning may garner positional identities such as intelligent or powerful. But if they were dark, might their positioning be compromised because Filipinos favor light skin (Constantino, 1978)? Or will their accents prevent them from being fully incorporated into the FilAm community? This complicated interplay of identities warrants a deeper dive into the experiences of Filipinos.

The structure-agency dialectic is central to identity studies. Structures are resources and schemas that enable social practices and systems to exist over space-time (Giddens, 1984; Sewell, 1992). Agency is the ability to shape and modify one's physical and social environment. This "structuration" theory foregrounds the conditions in which social systems are produced and reproduced and it highlights the role of structures in enabling or constraining the agency of people. Similarly, Sewell (1992) describes that structures shape a person's agency but also argues that agency also sustains and even transforms the very structure that shapes it. Giddens' and Sewell's framings suggest that structures take on primary roles in shaping agency. Salient to structures are resources and schemas. Resources, both human and non-human are used to enhance and maintain power and are unevenly distributed. Thus, agency can be defined as the ability to access resources (Sewell, 1992). While resources are actualizations of people's ideas, schemas exist virtually. They are rules that shape social life such as conventions, recipes, and habits of speech and gestures.

Understanding how FilAms negotiate their identities in science necessitates an understanding of power and how it shapes agency. Kockelman (2007) categorizes agency into two divisions that relate knowledge, power, and choice. Representational agency is related to knowledge and consciousness and residential agency is related to power and choice. Thus, representational agency can be used to understand whether FilAm students recognize the Whiteness endemic in science (Le & Matias, 2019) and residential agency can be used to understand whether they accept/reject Whiteness.

Research Questions

How does a FilAm identity interact with a science identity and how are experiences, expectations, and ideology implicated in this interaction?

This question challenges me to think more deeply about FilAm experiences within the AsAm diaspora in science. Answering this question aims to elucidate upon a tension between two structural forces unique to FilAms in science. One force is that Filipinos are imbued with a colonial mentality (David, 2013) which accepts Western culture as superior to indigenous culture. The other force is the Whiteness endemic in science (Le & Matias, 2019).

Research Design and Methods

My research design is an instrumental case study to explore a FilAm student's interpretations of his science experiences and the meanings he constructs from science concepts. I use critical inquiry because I am interested in exposing and disrupting the dominant racial paradigms in science by centering students of color (Solorzano & Yosso, 2002). I use an instrumental case study because FilAm experiences are complex, puzzling, yet specific (Merriam, 1998; Stake, 1995), and this student is an appropriate case because much can be learned from the intersections between his FilAm and science identities.

My data consists of researcher memos, three video-captured conversations and one captured on audio, class journals, and a sketch. The analysis first involved coding across two conversations and the sketch using multimodality (Maxwell, 2013). The transcript and the accompanying gestures, facial expressions, and speech patterns were coded for themes that spoke to a science and FilAm identity (Jewitt, 2009) followed by identifying specific meanings related to the themes (e.g. chemist, queer, mentor). Relationships were then established between the themes which resulted in the identification of various aspects of a FilAm figured world (e.g. family, nurses, Catholicism).

I establish the validity of this study in three ways. The first is by elucidating my positionality, beliefs, and biases as a FilAm physics teacher and scholar who is grounded in the belief that I do work for the betterment of my people. The second is cross checking the various data sources to ensure that the findings from each source are consistent with the others. The third is to member check and allow the student to review drafts for consistency and plausibility.

Preliminary Findings

Figure 1 (next page) shows the relationships between the themes generated from the analysis. The first round of coding showed two mutually shaping identities: a FilAm identity and a science identity. The next round analyzed specific descriptions of the student's identities and resulted in further refinement of these identities meant. His FilAm identity consisted of an academic pioneer and a queer FilAm. His science identity consisted of being a mentor, a chemist, and using a science-based belief system. Finally, identifying the relationships between the identities showed how the student's figured world of a FilAm in the US shaped both his identities. For example, his FilAm identity as an academic pioneer in his family and his desire to be a mentor are shaped by the narrative that FilAms in science are relegated to nurses, that FilAms are underrepresented in science, and that East Asians dominate the US Asian population in science.

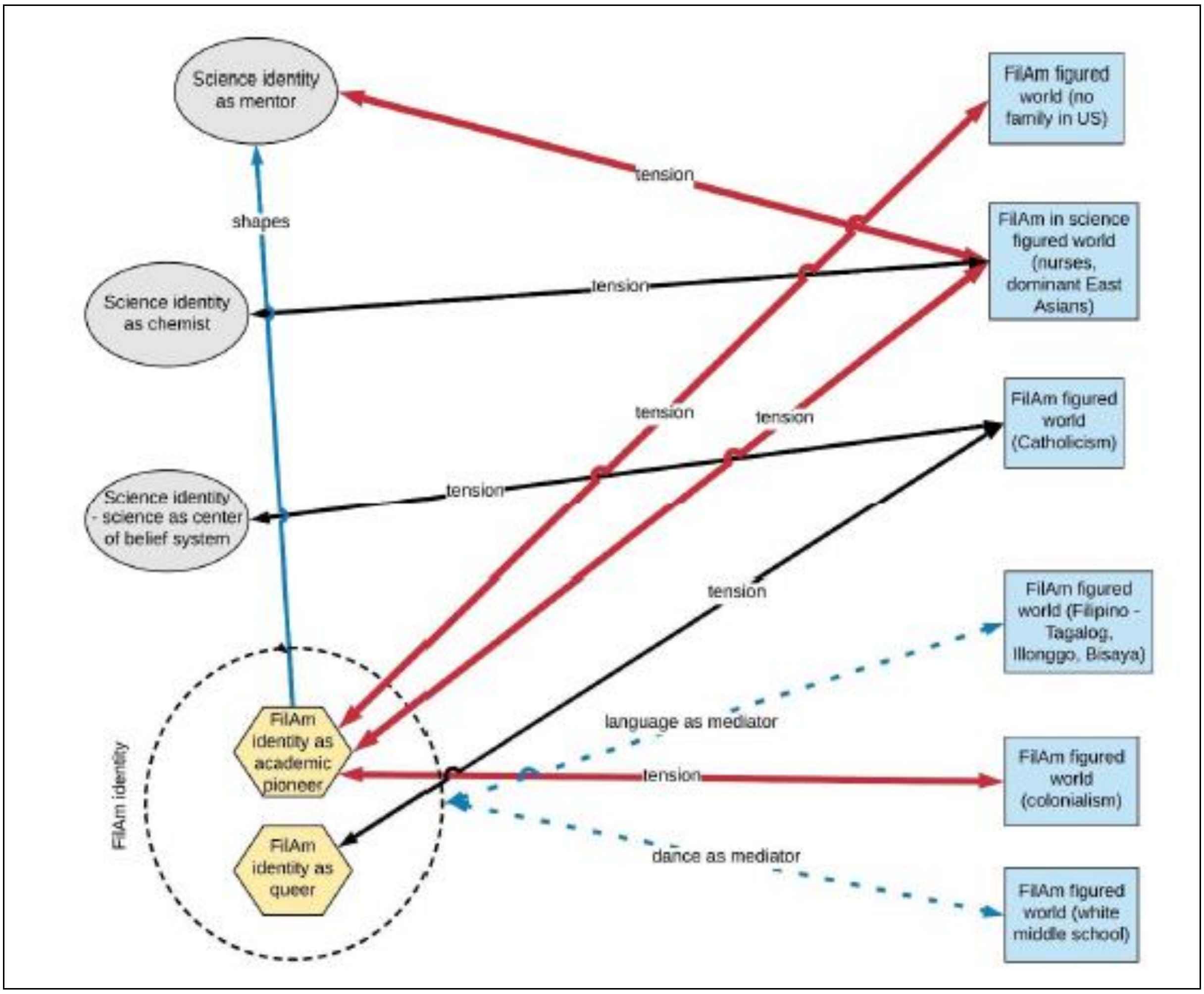

Figure 1. Concept map of student's identities and figured worlds.

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3.4 Mentor Group 4 | Weilanden | 3.4.2

Identifying Concepts in Individual Drawing Tasks to Prepare a Collaborative Work Phase

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Keywords: Chemistry, Secondary Education, Drawing, Machine Learning, Conceptual Understanding

Focus of the Study

The PhD project presented here focuses on the usage of learner-generated drawings, which are an important part of chemistry teaching. The problem is that learner-generated drawings are very time-consuming for teachers to evaluate. The aim of the project is to analyse drawings automatically with regard to chemical concepts. Therefore, the use of machine learning algorithms is being tested. Afterwards the created analysis tool will be applied in a real teaching setting.

Theoretical Background

Research Training Group

The PhD project is part of a research training group, which is the result of cooperation between educational researchers and computer scientists. It aims to explore the potentials and limits of data-based learning and teaching. The focus is on the development and evaluation of data-supported and intelligent methods (e.g. machine learning), as well as their meaningful integration in STEM teaching.

Learner-generated Drawings

Learner-generated drawings are highly relevant for chemistry teaching; exemplary positive effects are a facilitating integration of new knowledge into existing knowledge structures (van Meter & Garner, 2005) or the possibility to explicate conceptions (Wu & Rau, 2019).

For the analysis of learner-generated drawings in chemistry classes, an existing framework by Tang *et al.* (2019) will be used. This framework provides a first theoretical basis for the PhD project due to its high data base of 594 learner-generated drawings and a direct relation to chemistry education. The framework can be used to identify chemistry-specific features in learner-generated drawings, such as different levels of representation (Gilbert & Treagust, 2009) or the spatial orientation of objects.

Conceptual Understanding

Focusing only on subject content can be a barrier to learner-centred and evidence-based teaching approaches (Petersen *et al.*, 2020) and risks fragmented knowledge construction (Cooper *et al.*, 2017). Instead, it is suggested to explicitly formulate superior concepts that allow for a more connected knowledge construction (Pazicni & Flynn, 2019).

There are various approaches of such cross-thematic ideas, e.g. Basic Concepts (KMK, 2020), Anchoring Concepts (Holme *et al.*, 2015), Big Ideas (College Board, 2020) or Core Ideas (Cooper *et al.*, 2017; National Research Council, 2012).

For this PhD project, the Core Ideas according to Cooper *et al.* (2017) form a suitable theoretical basis. Cooper *et al.* (2017) define four Core Ideas that can be used to explain chemical phenomenon: (1) structures and properties of particles, (2) electrostatic and bonding interactions, (3) energy, and (4) change and stability in the chemical system. What makes the Core Ideas valuable for this PhD project is that they can be applied regardless of the country or age of the learners and are specific to the subject of chemistry. In addition, they do justice to the approach of cross-thematic ideas, which has already been successfully tested (Cooper *et al.*, 2019; Cooper & Klymkowsky, 2013; Mcgill *et al.*, 2018).

Machine Learning

Machine learning is an area of artificial intelligence. It can be divided into three areas: reinforcement learning, unsupervised learning and supervised learning (Lanquillon, 2019). Supervised learning includes classifying algorithms that can be used to analyse drawings (Ertel, 2016). In science education research, there are already positive examples of how machine learning algorithms can be developed and tested for STEM teaching (Yik *et al.*, 2021; Zhai *et al.*, 2021).

Research Questions

1. What drawing elements can be expected in learner-generated drawings for different Core Ideas?
2. How well is the categorisation of learner-generated drawing elements into Core Ideas?
3. How well does an ML algorithm categorise learner-generated drawings?
4. What group compositions, based on the individual concepts from the analysis of learner-generated drawings, foster learners' understanding of concepts?

Research Design and Methods

To answer RQ1, a framework of categories was created with the help of representations, which allows to assign drawing elements to Core Ideas. In the first step, canonical representations (N = 144) on all content areas of chemistry teaching were selected from 24 teaching communications (e.g. textbooks) using the method of theoretical sampling (Döring & Bortz, 2016). Representations were analysed instead of drawings, as similar elements were expected in both forms, but not enough learner-generated drawings were available at the time. In a next step, the representations were criterion-assigned by experts (N = 2) to the four Core Ideas according to Cooper *et al.* (2017). For the analysis of the representations, the framework of Tang *et al.* (2019) was adapted and extended by a fourth level "object classification". This level makes it possible to make more precise statements about which objects are related to each other and how. The representations assigned to Core Ideas were then coded. To be able to make statements about which characteristics can be expected to be (un-)specific to a Core Idea, outliers were calculated. In order to further substantiate the validity of the canonical representations, international teaching communications will be examined.

To answer RQ2, the developed framework of categories was tested on 31 learner-generated drawings from previous projects. For a more detailed evaluation, further drawing tasks will be developed, which will be completed by learners and subsequently analysed. In addition, semi-structured interviews (Niebert & Gropengießer, 2014) and the method of thinking aloud (Sandmann, 2014) are planned in order to be able to make more precise statements about which Core Ideas were predominant in the learners' work on the drawing task. For this purpose, students from University and from schools will be asked to participate. The data will be analysed qualitatively and content-analytically according to Mayring (2015).

To answer RQ3 a cooperation with a computer scientist from the LernMINT project is planned. Here, a classifying algorithm is trained and tested with learner-generated drawings. The required amount of learner-generated drawings is provided by processing the drawing tasks developed in RQ2. The quality of the algorithm is determined by the correspondence between human and machine coding.

RQ4 will be answered within the setting of the peer interaction method (Heeg *et al.*, 2020). The peer interaction method is a concept-enhancing teaching method that requires a quick analysis of learner-generated drawings and thus makes the algorithm from RQ3 useful. It is to be carried out in the classroom to ensure a realistic setting. The previously developed drawing tasks will be worked on and embedded in the task format of the peer interaction method. The learners will be videotaped while working on the tasks. The evaluation is carried out qualitatively and content-analytically (Mayring, 2015).

Preliminary Findings

When the ESERA Summer School takes place, the following results can be presented:

- Framework (IRR = 0.762) that assigns Core Ideas to drawing elements (RQ1),
- Evaluation of the framework using learner-generated drawings (RQ2),
- Hopefully first tested machine learning algorithms (RQ3).

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3.4 Mentor Group 4 | Weilanden | 3.4.3

Non-Formal Contexts for Primary Teachers' PCK, using Space and Astronomy

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Keywords: Non-formal Science Education, Primary Teachers Professional Development, PCK, Space and Astronomy Education, STEM

Focus of the Study

This study was first based on the researcher's professional and personal path in science centers, where according to Falk and Dierking (2018), people learn through their experiences with implications in the personal, socio-cultural, and physical dimensions. It became clear for school visits, that despite the orientations and materials made available to teachers to plan and integrate activities in the classroom, this collaboration rarely takes place.

To overcome this situation, we designed a professional development program for teachers, including non-formal education practices, with the support of the European Space Agency (ESA) to be carried out in various science centers in Portugal. This program uses Astronomy and Space as a non-formal and interdisciplinary context, involving different disciplines of science, technology, engineering, and mathematics (STEM), consisting of a sequence of inquiry-based science learning activities (Bybee, 2014). Moreover, educational kits were specially produced for this program.

The choice of recipients of this development program was on primary teachers, being their pupils at an early stage of schooling, with ages corresponding to greater changes in cognitive, social, and emotional development, in addition to their enormous natural curiosity.

Throughout this program, the need to better clarify changes that occur in teachers began to emerge, in terms of conceptual understanding, scientific knowledge, confidence, and motivation to teach science from a pedagogical inquiry perspective. For this purpose, this study focuses on the Pedagogical Content Knowledge (PCK) changes in participants, considered as the specific knowledge of teachers (Kind & Chan, 2019). PCK includes feelings (interest, motivation, and enthusiasm), and perceptions of teachers' self-confidence to teach science as well as the emotional aspects of being a teacher, no less important than content knowledge or pedagogical knowledge (Hestness, 2017). Keeping in line with the recommendation of Kind (2009), it is important to consider emotional factors involved in PCK, and more work is needed in this area to help dispel the notion that anyone with good knowledge of content can teach.

Therefore, the focus of this research is to understand what contributions a teacher professional development program, using Space and Astronomy in a non-formal context has in the PCK of primary teachers.

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Theoretical Background

Too many students continue to show insufficient scientific literacy and it is becoming clearer that the contents, the vision of science, and the traditional methods that still prevail, are not enough for science (Corrigan *et al.*, 2020) and therefore for science education, to respond to global actual challenges.

Meanwhile, non-formal science education has grown as a field of research and has made great strides in knowledge construction. NASA, (National Aeronautics and Space Administration) pioneered initiatives in education, followed by other space agencies, namely ESA, from 2000 onwards. Many of the space agencies developed poles of research and action in the field of education with links to universities and museums, science centers, and other institutions. Space and Astronomy learning contexts are inspiring and stimulate curiosity in all, particularly children. These contexts´ design is based on science and technology research and space agencies´ activity, focusing on current, and interdisciplinary issues with implications for our daily lives.
For many primary teachers, non-formal experiences can represent a significant portion of their exposure to science (Bell *et al.*, 2009), an opportunity to confront personal ideas with scientific reasoning, and a compelling (and sometimes initial) point of engagement with science.

What teachers do inside and outside the classroom, is the most important and the most direct contribution to students' cognitive and socio-emotional outcomes (OECD, 2021). However, Rodrigues *et al.* (2015) identified a deficit in teacher initial education, associated with a deficit in strategies/activities that integrate formal and non-formal education practices.

Lee Shulman (1986) described as insufficient to consider only the development of pedagogical skills, or only the appreciation of content knowledge, for teacher education and teacher training. He thus reinforced the notion of Pedagogical Content Knowledge (PCK), as a theoretical construct, for what the specific knowledge of teachers should be. PCK, when used in training processes, can help teachers adapt to teaching and can help more experienced teachers to develop more reflective practices (Kind, 2009).

However, according to Pinthong and Faikhamta (2017), studies are lacking on teacher training programs centered on non-formal contexts. They also question whether existing professional development programs consider the relevance of continuing science learning beyond school and whether they provide teachers with the necessary skills in the broad field of what science learning means.

It is necessary to investigate these new collaborative approaches, which must go beyond what have been the typical links between organizations (Kim, 2017). This leads us to question why science education has two distinct parts, formal and non-formal. Given the current reality perhaps we should rather consider a comprehensive teacher education and the diversity of educational organizations beyond schools, to develop the objectives of science education (National Research Council, 2012) and promote reflection in the teachers.

Research Questions

1. What is the effect of a non-formal development program about science education on primary teachers´ PCK to teach specific content?
2. Which PCK aspects do teachers develop?
3. What changes in teachers' emotions/attitudes (interest, enthusiasm, motivation) are observed?
4. What are the difficulties faced by teachers throughout the program?

Research Design and Methods

This is a qualitative study, with a problem in the field of personal and professional experience of a convenience sample of teachers and it is important to consider the (qualitative) meaning of the data and not its quantification or numerical value (Ghiglione & Matalon, 1993).

Participants' PCK is the focus of this study, which are a group of around 15-20 primary teachers enrolled in a non-formal professional development program of a Science Center, based in Earth and Space issues.

The research is organized through three main phases as represented in Table 1.

Table 1. Organization of research activities and stakeholders.

Research Phases	Activities	Stakeholders	Bibliographic Research
1st Phase: Fieldwork Preparation	- Preparing authorizations (Science Centre, participants, schools) - Planning the training program - Design and validation of data collection instruments - Validation of methodological strategies	Science Center Teacher test group Researcher Advisor	- Deepen the theoretical framework of the study - Deepen PCK data collection instruments - Justify methodological options, design and data collection instruments
2nd Phase: Fieldwork	- Description of participants - Implementation of the training program - Observation - Data collection during and after training - Readjustments in the planning resulting from data - Teacher´s class observation	Teacher Participants Researcher Advisor	- Justify the selection and processing of data - Justify the results based on theoretical framework of the study
3rd Phase: Data Analysis	- Analysis and processing of data - Data triangulation/validation - Results and conclusions of the study	Researcher Advisor	

I am presently at the first phase of the study, "Fieldwork preparation", designing the data collection instruments. Next February, a pilot-study will start to validate these instruments. The second phase, "Fieldwork" to collect the main data, is scheduled to November until March 2023.

A two-phase questionnaire will be applied, containing a CoRes to be fulfilled (Loughran *et al.*, 2004) and questions to detect misconceptions from participants. The study includes the analysis of teachers' productions (lesson plans, presentation, and individual reflection) as well as examples of their pupils´ work.

Following an interpretive analysis model, the qualitative techniques (Denzin & Lincoln, 2008) of the study favor the observation of participants during sessions and follow-up lessons in the classroom. We will use content analysis (Bardin, 2009) with internal crossover for validation of results.

Participants´ informed consent was required and the law of personnel and data privacy is assured as well as the research ethical recommendations issued by the University of Lisbon.

Preliminary Findings

Ongoing observations have shown positive changes on teachers' content knowledge, including identification and deconstruction of misconceptions. Improvements in pedagogical knowledge and knowledge of context were also detected. Some teachers referred improvements in their students' learning and attitudes. In general, teachers showed greater interest, enthusiasm and fewer constraints toward science and requested follow-up activities (teacher programs to school peers). Most teachers expressed their deficit in science and science teaching and the need for the continuity of this development program.

We hope the results of this study will promote more effective teacher education programs and improve teaching practices. We also hope to raise new questions and encourage future studies to the advancement in the field.

We assume that a common understanding and shared vision of relevant science education, claims for synergies across sectors and values all contributions to activate and engage science learners. We envision a framework basis for universities and non-formal institutions co-operating on initial teacher education and being part of a larger learning ecology.

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3.4 Mentor Group 4 | Weilanden | 3.4.4

Science Identities in Transition from 6th to 7th Grade

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Keywords: Science, Primary School, Participation

Focus of the Study

This project is inspired by the Aspires project carried out in a British context showing how interest and aspiration to science are already established in primary school and that the intersection of gender, social background and ethnicity play an important role when young people struggle to see themselves as a science person (Archer, Dawson, *et al.*, 2015; Archer *et al.*, 2010). They use the term science identity which have proven valuable as a theoretical lenses to understand why some children and young people can relate to science and whether they believe 'science is for them' when others feels alienated (Archer, Dewitt, *et al.*, 2015). Science identities contain an individual's sense of self to science and how other recognize one as a science-person (Archer *et al.*, 2013). Furthermore some young people finds it difficult to relate their interest and themselves to the way science is taught (Holmegaard *et al.*, 2014). The way science are taught and how science culture, practice and interests are played out in the classroom also have a high impact in how young people see themselves as a science person or not (Hasse, 2002; Hsu *et al.*, 2009). Research shows that young people often struggles with science in transitions between different institutions, subjects and settings (Gale & Parker, 2014). One of the more overlooked transition is the transition from 6 grade to 7 grade in the Danish public school (Folkeskole) where pupils goes from one single combined science subject (nature-technology), to three science subjects (biology, physics/chemistry and geography). This transition can be experienced as a challenging process because the teaching, the curriculum and the settings changes (Sølberg & Trolle, 2013).

Therefore, this project aims to create knowledge about the transition by examining pupils' participation and relation to science across the transition-phase. In particular, the inclusion and exclusion processes that arise in the interaction between pupils, teachers, curriculum and settings. A particular focus will be on identity work and how social background, gender and race interact with who is being recognized as, and recognize themselves as a science person. Attention will furthermore be given to how certain ideas of science are constructed and reproduced through relations and experience in and outside the classes. The results from the project shall provide new knowledge about making space for different kinds of participations in science.

Theoretical Framework

In this project, identity theory is applied to nuance the idea of identity as something fixed and isolated. Instead, identities are perceived as fluent and unfixed, constructed and negotiated inter-subjectivity and embedded in culturally-recognized practices and repertories (Hasse, 2008; Holland *et al.*, 2001). The processes of developing identities are the an interplay of negotiating and constructing of who you are (Holmegaard *et al.*, 2015). Though it is not only about positioning oneself but also a question of being positioned by others (Davies & Harré, 1990). Examining the development of science identity is key to this project. This provides an opportunity to examine if certain stereotypes or dominant ideas of science are being reproduced or maintained in the classroom and therefor creates less place for being acknowledge as someone who does science. Hedie Carlone and colleagues (2014) shows how some identities are celebrated and how they are mediated by race, class, and gender. Therefor this project draw at intersectional lens to understand how social class, gender, religion and race are linked in shaping an science identity (Avraamidou, 2019). A key goal in this project is therefor to examine scientific practices and what these practices offers to pupils when shaping, negotiating and constructing science identities. By examine these science identities, we gain insight into what is celebrated and how inequalities are maintained and reproduced in the science classroom influenced by gender, race, class.

Research Questions

The aim of the study is to explore which science identities that are made available, included and supported across science classes, and which are being challenged, neglected and excluded when the settings change. The core of the project is thus to understand the transition from the 6th grade to the 7th grade and the opportunities and challenges it presents to the pupils to participate in not only one single science subject, but in biology, physics/ chemistry and geography.

Research Design and Methods

This study uses qualitative methods: workshops, interviews and ethnographic fieldwork. Data is produced at three Danish schools over the course of one and a half years, with three separated periods of data production (see Table 1). However, interviews with pupils will only be completed at two of the schools. It is the same pupils interviewed in all three periods of data collection. The schools are called school W, X and Y.

Table 1. Overview of Data Production.

Period 1 (2021/22 (Fall/Winter)	• Workshops with science teachers at all schools (N = 14) • Three weeks ethnographic fieldwork at all schools • Interviews with six pupils, schools W and Y (N = 12)
Period 2 (2022/Spring)	• Workshops with the pupils (N = 50) • Interviews with the six pupils (N = 12) • Interview with the science teacher (N = 3)
Period 3 (2023/Fall)	• Two workshops with science teachers before and after the fieldwork • Three weeks ethnographic fieldwork • Interviews with the six pupils • Interviews with science teachers (N = 9)

The pupil interviews are carried out in the last week of the fieldwork. The fieldwork entails participation in all lessons with the class, but also in break activities in order to gain insight into the non-teaching context (Hammersley & Atkinson, 2007). In first and third period I conduct teacher workshops, inspired by action research (Stringer, 2008). In the workshops, we discuss concrete examples and dilemmas related to science teaching and the teachers share ideas of how to support different kinds of participation in the science classroom. The teacher interviews contribute to explore the teachers' experiences with teaching science, their thoughts and the challenges they encounter in terms of teaching science and supporting pupils' learning process.

Period two contains observations in science lessons, interviews and workshops with the classes. All of the interviews are inspired by performative, creative, and visual methods to support different forms of participation (Bagnoli, 2009). These approaches provides other ways of expressing (science) identities – by inviting feelings, ideas and perceptions into the interview.

The data will be analysed by applying a thematic analytic approach (Braun & Clarke, 2006). Using the software program Nvivo data will be coded first in an initial coding, looking for general themes, and second in a focused coding exploring selected themes. The analysis will furthermore explore and compare differences between the three schools.

Preliminary Findings

The project is currently in the beginning phase of the data production. Though, from an initial coding of data from the workshops with the science teachers and fieldwork from school X, some contours are however already forming. In one of the activities at the workshop, the teachers were asked to draw themselves as *how they saw themselves as science teachers*. In this exercise, two narratives were prominent 1) they saw themselves as an octopus or 2) standing at the desk explaining material. The octopus-metaphor was explained as an experience of dealing with a lot of different tasks at the same time; helping with experiments, explaining content and discussing results. The other image exemplifies the teachers as someone who stands at the desk while they try to provide the pupils' with knowledge to engage them. The two narratives show two different kinds of engagement, one where the teacher have to navigate different positions and one where the teacher holds a single position. At school X, one of the teachers portrayed himself through the second narrative, which during the fieldwork turned out to correspond very much to the way he taught. This teaching practice can be seen as a traditional way of teaching, where the pupil's participation occurs through the answering of questions asked by the teacher and where the pupils are placed at their table. One of the pupils disrupted this teaching form. The pupil asked if she could join the teacher at the desk – she got permission. This situation contradicted with the teacher's image of engaging the pupils from the desk. Through this interaction the pupil was not bound to her table and that created another participation – she became engaged with the material in a more dynamic way. Interactions like this will be analysed to understand how different ideas of teaching influence ways for participating. This will be viewed from an intersectional lens to see how these participations are enabled and how they are experienced as either possibilities or constrains.

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‘‘An acid is that green stuff that’s dangerous, and what’s a base?’’ – Teaching about Acid-Base Reactions in Upper Secondary School

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Keywords: Chemistry, Secondary Education, Acid-Base Chemistry, Design-based Research

Focus of the Study

Acid-base chemistry plays an important role in our lives because of its real-world application: Biochemical processes often include acid-base reactions. Everyday products such as cosmetics or food (partially) consist of compounds reacting as acids or bases, and numerous industries either apply acid-base reactions as a means of production (e.g., chemical and biochemical industry, metal industry), or use products of acid-base reactions like fertilisers and construction materials (e.g., agriculture, construction industry). Consequentially, the topic is an important part of the Austrian chemistry curriculum (BMUK, 2016). However, acid-base chemistry is difficult to teach and learn: On one hand, a large number of everyday substances is known as ‘acids’ and ‘bases’. On the other hand, such designation remains ambiguous regarding the chemistry-specific terms for the particles involved in acid-base reactions which are introduced in chemistry classrooms (Taber, 2013). We aim at contributing to a coherent introduction of acid-base reactions via constructing a learning environment (LE). In our design-based research project, we adapted the Brønsted-Lowry model of acid-base reactions for Austrian upper secondary school students. By applying the approach of Educational Reconstruction (Duit *et al.*, 2012), we formed key ideas (KIs) as the basis for an LE. We subsequently interviewed students (N_1=7, N_2=4, N_3=7) utilising the method of probing acceptance (Jung, 1992), and thus ascertained the functionality of the developed explanations and tasks. The results of the preliminary study are currently used for the development of the LE. Finally, the LE itself will be evaluated via a pre-post assessment (N=90) which accounts for a growth in content knowledge of the participants.

Theoretical Background

Acid-base reactions are an essential part of chemistry and chemistry education, both in terms of subject content and curriculum (e.g., Rychtman, 1979). However, numerous alternative conceptions about 'acids' and 'bases' exist over a wide range of chemistry students with regard to, e.g., age or school level (e.g., Hoe & Subramaniam, 2016). Furthermore, (prospective) teachers’ conceptual uncertainties and ambiguities about the topic have been identified (e.g., Alvarado *et al.*, 2015; Lembens & Becker, 2017). Holding such an ambiguous understanding of, e.g., acids as substances, aqueous acidic solutions as well as their respective symbolic representations is a major cause of learner confusion (Johnstone, 1991; Reid, 2021; Taber, 2013). Accordingly, we claim that research is needed on how to teach the topic effectively, i.e., on how to connect technical language, subject matter, and compatibility to other reaction types.

Research Questions

Our project focuses on how ‘acids’ and ‘bases’ can be taught appropriately in upper-secondary schools. We emphasize supporting learners in building a scientifically appropriate and compatible understanding of acid-base reactions. The research goal is further specified by the following sub-questions:

1. What aspects of the topic are suited to form initial explanations and to develop an effective learning environment for learners at upper secondary level?
2. To what extent are initial explanations of acid-base reactions understandable and plausible for the learners and applicable to more advanced tasks and problems?
3. To what extent is the learners’ knowledge about acid-base chemistry influenced by the proposed learning environment about acid-base reactions?

Research Design and Methods

Figure 1 gives an overview of the research design. The study’s KIs emerged from our problem analysis (cf. theoretical background) and a subsequent Educational Reconstruction (Duit *et al.*, 2012). They are based on an analysis of the science content (e.g., Brønsted, 1923), and research on teaching and learning (analysis of textbooks and previous teaching and learning sequences, research on alternative conceptions about the topic; e.g., Lembens *et al.*, 2019). The KIs cover the main aspects of the topic with regard to the target audience, i.e., Austrian upper secondary learners of chemistry. The preliminary study consists of three interview rounds (N_1=7, KIs 1-3; N_2=4, KIs 1-5; N_3=7, KIs 1-6) and leads to the evaluation of the KIs in terms of effectiveness via the method of probing acceptance (Jung, 1992).

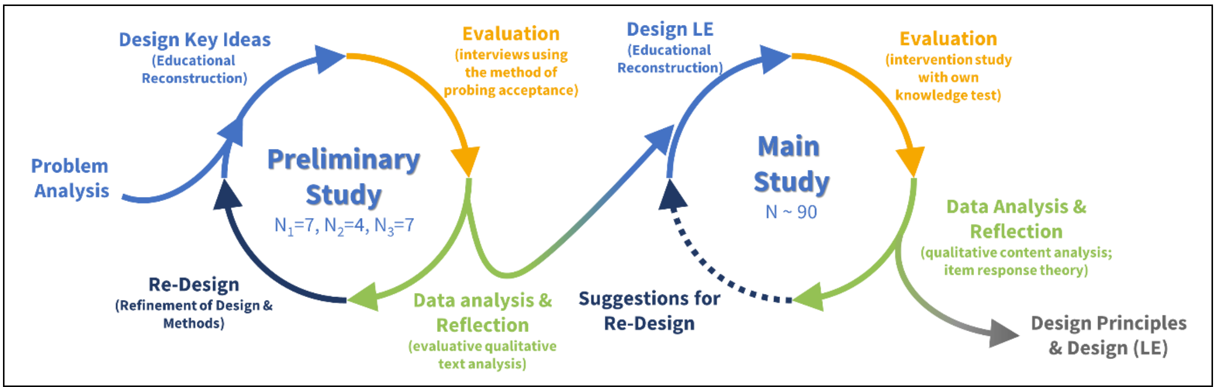

Figure 1. Overview of the research design.

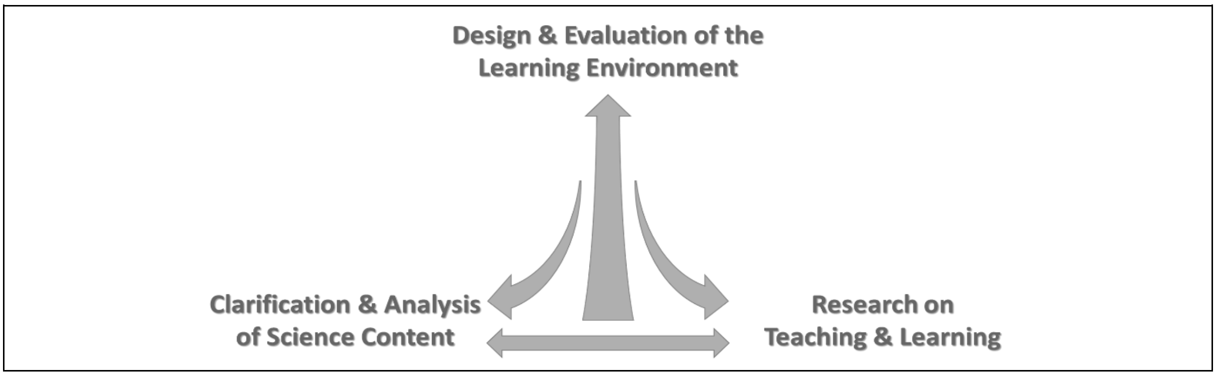

Figure 2. The Model of Educational Reconstruction (Duit *et al.*, 2012).

The participants evaluated the KI-based explanations with regard to comprehensibility and understandability, paraphrased the explanations, and finally applied them to one or two tasks of increasing complexity. We used qualitative text analysis (Kuckartz, 2014) to assess the level of acceptance the learners display towards the KIs. In the main study (N=90), an LE is currently being designed based on the preliminary study. This LE is evaluated in a pre-post setting. To that end, we constructed a knowledge test about the Brønsted-Lowry acid-base concept, which, in turn, is based on an Educational Reconstruction of the concept (Krebs & Lembens, 2021) and supplemented with additional items from field experts (Emden *et al.*, 2015). Overall, 25 items were administered to Austrian upper secondary students (N=134) to pilot the test. We used Item Response Theory both as our conceptual framework for constructing the tasks (Wilson, 2005), and for analysing the obtained responses (Wu *et al.*, 2016).

Preliminary Findings

RQ 1: Educational Reconstruction and Development of the Key Ideas

The Model of Educational Reconstruction (Figure 2) was employed to develop the following KIs as the basis for the research endeavour (Krebs & Lembens, 2021):

KI 1. Brønsted acid-base reactions are protolysis reactions (Brønsted, 1923).

KI 2. Acids and bases exist as particles in the course of the acid-base reaction; the donor-acceptor concept is highlighted (Barke & Harsch, 2016).

KI 3. The Electron Pushing Formalism explains bond breaking and formation during the reaction (Sieve & Bittorf, 2016).

KI 4. Acid-base reactions in aqueous solutions are often reversible.

KI 5. Beaker models and the pK_a/pK_b table are used to consider acid and base strength (Barke, 2015).

KI 6. To highlight the connection between the particles (acids, bases) and substances (acidic and basic solutions), simulations and experiments such as the one by PhET Interactive Simulations (Lancaster *et al.*, 2021) can be used.

RQ 2: Evaluation of the Key Ideas

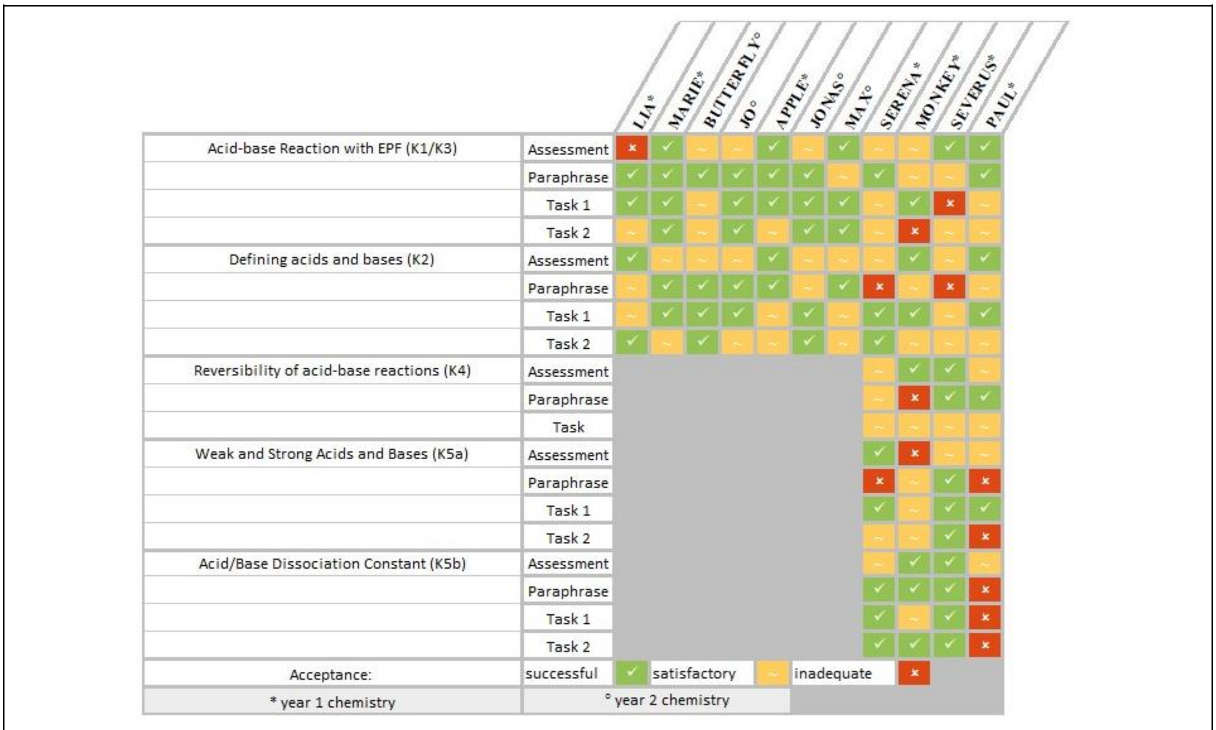

Figure 3. Results of the evaluative qualitative text analysis of interview rounds one and two (Krebs & Lembens, submitted).

Figure 3 depicts the findings from the three interview rounds. The first round of interviews suggested a worthwhile approach, yet also implied a need to revise our KIs, explanations, and tasks for acid and base strength in the second interview round. The data from interview round three has not been analysed fully yet.

RQ 3: Evaluation of the Learning Environment

The final LE is currently being developed based on the data from the preliminary study. For assessing knowledge gains, we constructed and piloted a 25-item acid-base knowledge test. Its item reliability was considered adequate (WLE-Rel.=.64, $Infit_{min}$=.87, $Infit_{max}$=1.01, $Outfit_{min}$=.87, $Outfit_{max}$=1.00) and item difficulty rather high (range from -.53 to 1.8). Consequently, 22 of the 25 piloted items will be utilised for an intervention study of the LE.

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3.4 Mentor Group 4 | Weilanden | 3.4.6

Nursing Students and Empathic Attitude: Educational Needs and Training Perspective in the Time Post Covid-19

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Keywords: Education, Life-long Learning, Empathy, Reflective Practice

Focus of the Study

The provisional title of the doctoral thesis that is being carried out is 'Nursing Students and empathic attitude: educational needs and training perspective in the time post Covid-19'. This doctoral research is being carried out in the field of Health Pedagogy and Health Professions. The study in question aims to define and partially implement some experiences oriented to implement reflective thinking in health professionals and accompany them to understand the constructive value of their own experiences, to recognise the variations in their reasoning (metacognitive dimension), to process the emotional experiences inevitably connected to the position of the protagonists within the care relationship (relational dimension) and to make them able to contextualise the care action (pragmatic dimension). The recipients of this research are students of the Degree Course in Nursing Sciences at the University of Padua and Ferrara enrolled in the second year, who began their training in the middle of the Covid-19 pandemic.

Review of Literature

Firstly, we tried to assess what the training needs of these young people are. This definition required us to circumscribe the cognitive dimensions subject to observation and they were identified in:

- Area of understanding the level of emotional self-awareness;
- Critical and self-critical capacity of these subjects to evaluate the profession they propose to pursue in the future;
- Intensity of their vocational choice.

We focused the literature review on adult education by exploring pedagogical theories on the clinical pathways of training of health professionals (Maslow, A.H., 2010: Motivation and personality; Zannini, L., 2005: Tutorship in adult education: a pedagogical view), life-long learning (Knapper, C., & Cropley, A.J., 2000: Lifelong learning in higher education) and medical education (Schön, D.A., 1993: The Reflective Professional: for a new epistemology of professional practice; Mortari, L., & Saiani, L., 2013: Gestures and thoughts of care; Bertolini, G., & Massa, R., 1997: Clinics of medical education).

This review has made it possible to understand how in the Health Professions of the Nursing Sciences a significant part of the training course involves the transmission of a series of techniques that once learned go to constitute the baggage of practical knowledge of the professional and that if applied correctly provide the basis of safety essential to the performance of this work. The gap that can be created in the future professional is between the routine execution of a learned technique and the understanding, acceptance and listening to the subjective dimension of the person to whom the manoeuvre is addressed: if the latter is not properly managed, the former may not be sufficient to ensure the quality of one's professional practice. The lack of in-depth theoretical study connected to the relational-communicative dimension that is often evident in the degree courses of the health professions is combined with the limited consideration of the diversity of the relationship that can be established between nurse and patient depending on the duration and continuity to which that relationship is destined: dealing with a chronic patient is completely different from managing an acute patient, yet this aspect also does not appear to be contemplated in the protocols and job descriptions. This technical training, which from a strictly pedagogical point of view appears to be deficient because of what has just been described (Jarvis, 2018), is often associated with the construct of training, which has become the next object of theoretical investigation in order to compare it with other approaches to training, for example transformative learning (Mezirow, 1991) and Critical Thinking (Paul, 1995). We stayed in Reflective Practice because we have found several studies that relate empathy to reflective practice skills (Charon, 2004; Chen, 2014; Gill, 2014; Stanley, 2020).

The Theory of Reflective Practice in Nursing is a middle-range theory that mainly proposes that nurses must practice reflection-before-action, reflection-in-action, reflection-on-action, and reflection-beyond-action to advance nursing practice (Shon, 2008; Edwards, 2017).

The idea of reflection as a valuable tool to assist nursing students in learning from practice (Jootun & McGarry, 2014) is based on the one hand on the belief that reflection helped uplift the status of nursing as a profession (Edwards, 2017) on the other hand is considered instrumental in helping nurses provide optimum care to patients (Caldwell & Grobbel, 2013). Reflection involves a detailed exploration of a clinical situation or experience which includes an analysis of personal feelings, thoughts, and actions or behaviours. It entails cognitive activities such as description, critical analysis, evaluation, and planning. “Reflection is also a way of learning from a clinical situation or experience. It is a means by which feelings, perspectives and/or behaviours change. Moreover, reflection is an active and dynamic process” (Galutira, 2018).

Research Questions

What and how many changes with regard to certain chosen dimensions and what acquisitions in terms of critical-reflective thinking can be produced by an educational path defined according to a "capability" approach?

Research Design and Methods

The methodology chosen is deductive, since it is an itinerary that aims to proceed from theoretical hypotheses to their control and verification at an empirical level (Baldacci, 2001). The further level implied a review of investigation techniques and practices. In the international literature, especially Anglo-Saxon, many researchers have highlighted the potential of a mix-methods, qualitative-quantitative approach (Flick, 2018; Creswell, 2011). This allowed us to consider the use of some validated questionnaires that seemed consistent with our need to survey large numbers (the total sample will be 400 students) and find some clues about the attitudes of these young people towards certain content: levels of satisfaction of their vital needs, resilience, professional quality of life and empathic attitude.

At the same time, attention was also paid to the construction of a qualitative dimension of the survey. For this second part, it was decided to adopt an andragogical perspective (Knowles, 1978) sharing the assumption that adults need to understand their own training needs, should be able to choose what to learn and need the content of the training proposals to be aimed both at the acquisition of knowledge, skills and attitudes, and at their re-elaboration in a perspective of continuous human development of the person.

This approach contributed to make empathic attitude emerge as one of the central themes of the research: sharing the position of some researchers according to which empathy is a skill that can be acquired, we believe it can be the object of training experience. Given this evidence, we have expanded the theoretical framework and taken into consideration a particular construct often present in curricular experiences to which future care professionals are exposed: the right emotional distance. Considering it an ambiguous construct in its indefiniteness, we believe that an experience of meta-reflection based substantially on the awareness of one's own empathic attitudes can become a vehicle for learning a different way of experiencing the relationship with the patient. On the basis of these considerations, we intend to propose for each seat of the two degree courses an experimental workshop led by the pedagogue and oriented to stimulate in the students active listening skills and re-elaboration of the contents emerged from the listening.

A part of the students, chosen through a randomization carried out with SPSS, will be involved in an experiential workshop. This activity should make it possible to alert other cognitive dimensions, such as critical thinking and metacognition: bringing out and naming the emotional experiences that are not normally addressed can transform the attitude towards the self and towards others in the future professional. We believe, therefore, that this experience can be a positive stimulus not only in terms of personal and professional growth, but also a moment of reflective learning.

The collected data, both quantitative and qualitative in nature, were subjected to analysis using dedicated software (SPSS; Atlas.ti).

Preliminary Findings

The students involved last year completed the validated tests at the end of their placement and the same cohort will complete them again at the end of their last placement before graduating. Analysis of the first survey data in the Interpersonal Reactivity Index confirms our initial hypothesis that students do not expose themselves emotionally. Therefore, we expect that the sample of students who will participate in the intensive experiential workshop will have different outcomes in testing than the whole sample. Furthermore, we expect that in the final focus group testimonies these students will have greater capacity to analyse the problem by referring to Gibbs' reflexivity cycle and will be able to recognise at least one cognitive bias in their empathic actions.

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Achieving Model Competence in Primary Education: Comparison of Instructional, Scaffolded or Error-search Learning Settings

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Keywords: Science, Primary Education, Model Competence, Instruction, Scaffolding, Error Search, States of Matter, Water Cycle

Focus of the Study | Theoretical Background

Scientific modelling is a process through which children learn how to generate and organize their own representations during their observations of complex natural phenomena, hence modelling is considered an essential competence in STEM (Treagust *et al.*, 2002). Despite the widely accepted usefulness of modelling in education, modelling-based learning is seldomly incorporated into practice, especially in primary education (Louca *et al.*, 2011; Schwarz & Gwekwerere, 2007). Even worse, models are often depreciated to illustrative purposes, leaving the learner with materials that implicitly demand model competence in order to read, understand and communicate about models and their represented scientific ideas (Gogolin & Krüger, 2018; Schwarz *et al.*, 2009). Knowing, understanding and working with models − referred to as model competence − is not trivially achieved and must therefore be taught explicitly (Booth *et al.*, 2013; Upmeier zu Belzen & Krüger, 2019). Most children's understanding of models was found to be rather naïve (Grünkorn *et al.*, 2014). Hence, it is argued that emerging model competence can and should be established in primary education to facilitate learning and found scientific literacy (Louca *et al.*, 2011).

In order to gain scientific literacy, one key aspect of model competence is transferring observations of phenomena into a model (Krell *et al.*, 2013). An example for a model that is widely integrated into curricula for primary schools is the water cycle, including the topic of different states of matter. Here, learners are reported to have difficulties with changes in the state of matter and with describing the underlying processes (Gogolin & Krüger, 2018; Wang & Tseng, 2018).

Overall, there is little prior research on appropriate learning settings that might facilitate model competence. Lange-Schubert *et al.* (2017) put forward that primary school children are able to work with models with the help of explicit instruction. Indeed, instructional learning settings are known for effective learning and reduction of cognitive load (Renkl, 2014; Sweller *et al.*, 2011). In this context, recommendations of cognitive load theory state that all relevant information should be made available for learning in order to avoid cognitive overload (Kirschner *et al.*, 2006; Sweller *et al.*, 2011). However, it is criticized that making all relevant information available may result in so-called "inert" knowledge that cannot be applied in transfer tasks or new problem contexts (Renkl *et al.*, 1996). One facilitation strategy to help learners overcome difficulties during learning is to provide assistance by scaffolding (for a review, see Lin *et al.*, 2012). In scaffolded learning settings, a learner is supported to complete a task by providing guidance or structure to the material at hand. Although scaffolding is rather common in teaching and widely known to be effective for learning, too much scaffolding may turn detrimental if students rely on it.

Another rather promising learning setting to achieve cognitive activation is learning from errors (for a review, see Metcalfe, 2017). Here, learners are asked to discover errors within the learning material and justify why they are incorrect. In theory, reflecting on errors leads to an increased understanding by raising awareness on wrong alternatives in contrast with the correct solution (Oser *et al.*, 2012). Although learning from errors is an approach that received rather little attention in educational research, some studies indicate its' effectiveness for long-term learning and transfer in new problem contexts (Booth *et al.*, 2013; Große & Renkl, 2007). Hence, the study presented here aims at providing empirical evidence for the effectiveness of the three learning settings in the context of model competence.

Research Questions

The goal of the proposed study is to investigate the impact of the three learning-settings (i.e., Instructional, Scaffolded and Error-Search learning settings) on learners' model competence in the context of the water cycle in primary education. Hence, the project is guided by the following research questions:

1. To which extent does the learning setting impact learners' model competence?
2. To which extent does the learning-setting impact learners perceived cognitive load?

Based on the literature, we expect learning gains in all three Treatments. However, long-term learning is expected to be more beneficial in the Error-Search Treatment compared to the other. Cognitive load is expected to increase from the Instructional to the Scaffolding to the Error-Search Treatment. Prior knowledge and cognitive abilities will be included as co-variates.

Research Design and Methods

According to the research questions, the results from three treatment groups (Instructional, Scaffolded and Error-Search Treatment) will be compared. The study design will follow a randomized-controlled intervention including quantitative pre-, post-, and follow-up-tests. An a-priori power analysis to obtain statistical power at the recommended .80 level (Cohen, 1988) suggests a sample size of approximately 270 participants to reveal a medium effect size ($f = .25$).

While the intervention and the post-test will take place in the out-of-school laboratory, the pre- and follow-up-test will be performed in the learners' schools (see Figure 1). Learners' cognitive abilities will be assessed prior to the out-of-school lab. The tests will assess model competence and subject knowledge concerning the topic of the project day, the water cycle and the states of matter of water. During the intervention, learners' will be asked to rate their perceived cognitive load at several occasions (Klepsch *et al.*, 2017).

The out-of-school laboratory day is structured into three phases (Figure 1). In the introduction-phase, the topic is contextualized and occurring phenomena of the water cycle are problematized. In the laboratory phase, learners will carry out experiments in groups with regard to the questions on the topic of water cycle and states of matter. This is followed by an intervention – the conclusion-phase – where learners will have to integrate their observations from the experiments into a comprehensive model of the water cycle. In this third phase, learners will be randomly assigned to one of three treatments (see above). While learners in the Instructional Treatment receive a complete and correct model, learners in the Scaffolding Treatment will be presented to all relevant, individual entities but would be prompted to connect these entities into a meaningful, structured model. In the Error-Search Treatment, learners are asked to identify and correct purposefully incorporated errors in a given model. Subsequently, there will be a brief feedback to the learners if they have solved the tasks from the conclusion-phase correctly.

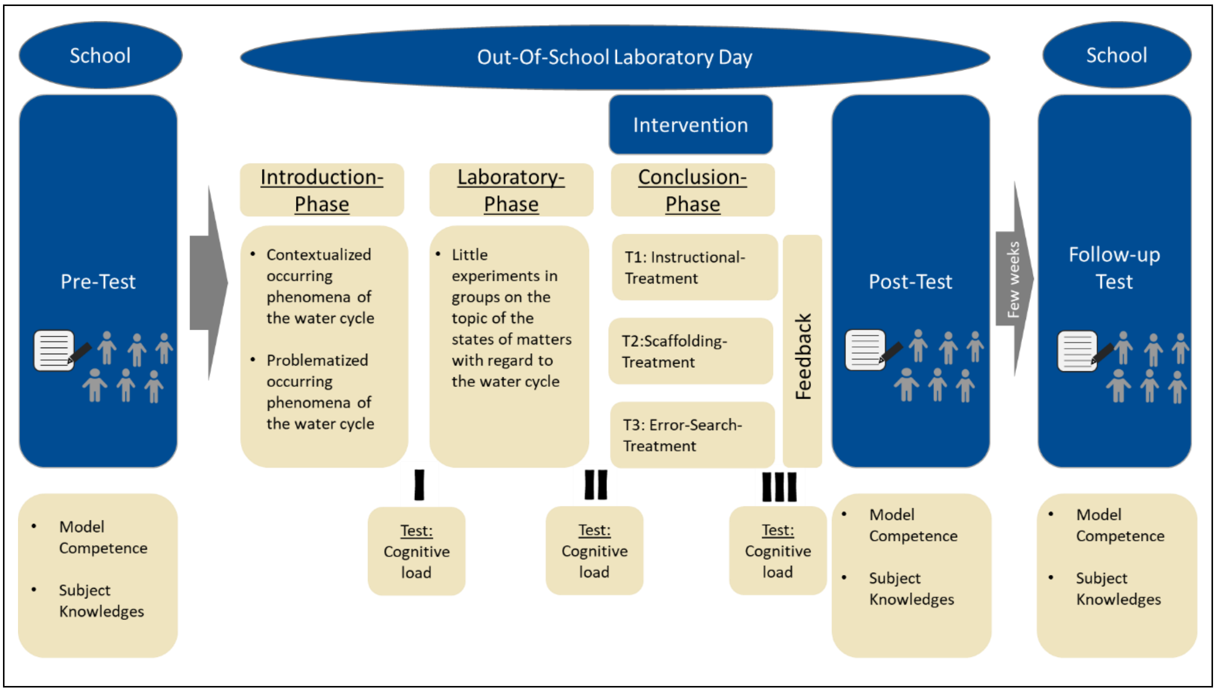

Figure 1. Overview of the research design.

Preliminary Findings

By the time of the summer school, all tests and materials will be finalized. The lab day including the experiments on the topic of states of matters of water will be developed. The material of the three learning settings will be finalized and piloted with two or three classes (40 to 60 students). We expect to have first results to present at the summer school.

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3.5 Mentor Group 5 | Sloten | 3.5.1

Queer in STEM: LGBTQIA+ Students' Experiences in STEM Learning Environments

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Keywords: STEM, Science Identity, Queer Theory, LGBTQIA+, Life Stories

Focus of the Study

A large and growing body of literature has reported that persistent inequalities within science secure the privilege of white males while women, people of color, and persons with disabilities are consistently underrepresented and discriminated in STEM (EC, 2021; NSF, 2021). Of interest to this study are the experiences of LGBTQI+ individuals (queer from now on) in STEM, who are both an "underrepresented and underserved" community in STEM (Patridge, Barthelemy & Rankin, 2013, p.78).

A synthesis of the work related to queer individuals' experience in STEM shows that researchers have focused their attention to an examination of the culture of STEM working or learning environments and the negative experiences of queer people in STEM. A set of studies indicated that queer individuals in STEM fields experience exclusion, discrimination, harassment vis-à-vis their sexual and gender identities (Barthelemy, 2020; Bilimoria & Stewart, 2009; Cech & Waidzunas, 2011; Costa *et al.*, 2016; Kersey & Voigt, 2020; Miller, Vaccaro, Kimball & Forester, 2020), and negative career consequences (Cech & Waidzunas, 2021). Another set of studies showed that queer individuals were more likely to leave a STEM trajectory than their non-queer peers (Hughes, 2018; Patridge, Barthelemy & Rankin, 2014).

A question that arises from these findings is what affirmed their identity and kept queer individuals persistent in their STEM trajectory. Such knowledge could help the science educational research community to create affirmative engaging opportunities for queer students in STEM. This is precisely what this study aims to do by attempting to shed light on queer individuals' STEM trajectories throughout schooling and university. More specifically, this research study will examine queer STEM majors' science identity as lived experience and try to understand what fostered and what hindered STEM participation throughout their science trajectories. For this purpose, biographical interviews and communicative focus groups with queer STEM majors will be conducted and analyzed.

Theoretical Framework

Science Identity

Science identity can broadly be defined as "who we think we must be in order to engage in science" (Barton, 1998, p. 380) or how an individual themselves as a science person and how they are recognized by others (Carlone & Johnson, 2007). Research has consistently shown that the formation of students' science identity plays a critical role to engagement (Brickhouse, 2012; Tan and Barton 2008) and persistence in science (careers) (Tujillo & Tanner, 2014), which are both connected to socio-political issues of exclusion in science.

Queer Theory

Although often associated with gay and lesbian studies, queer theory goes beyond normalizing homosexuality, to disrupt the very idea of heterosexual / homosexual binary (Gunkel 2009; Kersey & Voigt, 2020). More than that, queer theory aims to disrupt all kinds of normative processes, categories, and definitions (Gunkel 2009). Therefore, providing a definition for queer theory is a great challenge (Snyder & Broadway, 2004).

Queer theory draws its theoretical underpinnings in the poststructuralist work of Derrida and Foucault, and as such, considers identity as socially constructed (Gunkel, 2009). Essentialist views of a static identity are fully rejected and replaced by a dynamic, unstable, and shifting construct; "a contradictory and unfinalized social relation" (Britzman, 1995, p. 68, in Kersey & Voigt, 2020).

By applying queer theory to education, researchers can highlight and disrupt the heteronormativity of schools, meaning the cultural practices that reinforce heterosexuality as normal (Snyder & Broadway, 2004). Moreover, they can create space for non-heteronormative identities not only by giving the floor to marginalized identities and stories, but also by questioning 'what counts as knowledge […] how knowledge is constructed and who constructs it' (Gunkel 2009, p. 66). Especially in the case of science education, studies have indicated how heteronormative ideas and sex/gender binaries are being promoted (e.g., Snyder & Broadway, 2004). Gunkel (2009) argued that the emphasis of science education on some skills such as classification might promote the false ideas that every object and organism is to be classified, organized, labelled so as to fit into predetermined natural categories and anything not fitting into this 'neat package' will be viewed as not normal.

Queering science education means, among others, to resist the binary thinking. Queering science education does not mean to sexualize education, but rather to highlight that it is already sexualized, but only heterosexualized and remains explicitly heteronormative (Fifield & Letts, 2014; Snyder & Broadway; 2004). One of the goals of queering science education would be to disrupt binaries such as heterosexual/homosexual, straight/ gay, female/male, woman/man, and masculine/feminine. Kersey and Voigt (2020) suggested one way to do so is by "telling stories about those who do not fit into this binary and learning from narratives outside of the dominant culture (p. 5).

Research Questions

The research questions of the study are the following:

1. How did the participants form their science identity throughout schooling and university education?
2. How do the participants' queer identity and other multiple identities intersect with their science identity trajectory?
3. What kinds of experiences affirmed the participants' science identities and fostered their STEM participation?

Research Design and Methods

For the qualitative case study, data will be collected through 5 biographical interviews and 2 communicative focus groups with queer STEM majors (see Table 1 and Table 2). Participants will be STEM majors self-identifying as queer. Interviews and focus groups will be transcribed and analyzed through narrative analysis in order to make sense of the participants' life stories. My goal is to understand the construction of the participants' identities as well as the role of the social context and to highlight critical events that fostered/hindered science participation and supported and the construction of queerness and science as compatible/incompatible.

Table 1. Data collection.

Data	Number	Participants
Biographical interviews	2-3 one-hour-long interviews with each participant (Total: 10-15)	5
Focus groups	2 focus groups	7

Table 2. Timeline.

Task	Month
Recruitment of the participants Interview & focus group protocols	January - February
Pilot study (interview 1 participant + 1 focus group)	March
Data collection (interview 4 participants + 1 focus group)	April - May
Development of coding scheme	April
Data analysis	May - July

An intersectionality lens will be used to investigate how their queer identities intersect with their science identities. Engaging in educational research with an intersectionality lens, open ups spaces where researchers can move beyond single-axis analyses (race, class, or gender) and account for the way race, class, and gender among others interrelate and shape education's dynamics of power and students' identities. Students' "identities are shaped by [their] experiences in social groups and how as members of those groups [they] encounter institutionalized social structures" (Tefera *et al.*, 2018, p. vii, viii).

Preliminary findings

The study is currently at the stage of finalization of the interview and focus group protocols and recruitment. Findings from the analysis will be presented in the ESERA summer school.

The findings of this study are expected to shed light on intersections of STEM and queerness and on issues of belonginess and identity throughout participants' STEM trajectories. We expect to present 1) what kinds of people were constructed as 'typical' STEM people in the learning environments the participants were part of; 2) where they placed themselves in accordance with these expectations; 3) whether their queer identity was constructed as compatible with these expectations; and 4) if yes, how, but if not, how they managed to persist in STEM trajectories. The findings will indicate whether participants feel they belong in STEM or ended up in STEM through resilience and despite of their queer identities.

Furthermore, we expect the participants to share several experiences that fostered STEM participation, including positive learning experiences in and out-of-school, critical events, important others, etc. We aim to focus on the experiences that fostered science engagement and at the same time affirmed the participants' queer identities or constructed STEM as fields that welcome different groups of people.

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3.5 Mentor Group 5 | Sloten | 3.5.2

Scientific Knowledge Practices in a Digital Learning Environment

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Keywords: Physics, Secondary Education, Scientific Practices, Collaboration

Focus of the Study

Scientific knowledge practices or scientific practices (SPs) reflect the multiple ways in which scientists explore and understand the world and are similar to expert performance in science, such as asking questions, planning and carrying out investigations, analysing and interpreting data, developing explanations, and building models (Krajcik & Shin, 2015). It was highlighted, that through participation in SPs students develop usable forms of both the epistemology underlying the scientific endeavour and explanatory scientific ideas (Duschl, 2008). Since digital learning environments (DLE), where widely available information is accessed, are becoming common features of learning, it is important to investigate use of SPs in a DLE. This research pursues to explore how SPs are enabled and used in a DLE.

Theoretical Framework

This research follows perspectives on learning based on sociocultural idea of knowledge construction through the interdependence of participants interacting with each other and tools and objects in their environment (Säljö, 2010) and trialogical learning approach (Paavola & Hakkarainen, 2009). Within these theoretical baselines, this research puts knowledge practices to the front. Recent studies examined how students learn from engaging in knowledge practices (Laakkonen and Muukkonen, 2019; Damşa & Muukkonen, 2019) in the context of higher education. In case of secondary school science, SP use as a part of the learning process has been emphasized in literature (Berland *et al.* 2016; Inkinen *et al.*, 2020) and recognized in the curricula (Finnish Ministry of Education and Culture, 2013). Though learning is supported more frequently through DLEs, the active role of students in using digital tools has not yet been realized in practice (Lillejord *et al.* 2018; Tanhua-Piiroinen *et al.* 2019). Access to DLE does not provide knowledge building, but it can be a context for SP: when used in a DLE, SPs intertwine with digital competencies and collaboration situations and promote learning as depicted above. The digital resources, in this case, can be used both as tools and objects of joint exploration.

Research Questions

The research is guided by the following research questions:

1. What are the general patterns of SP use during collaborative work in a DLE? How are SPs associated with collaboration situations?
2. What are students' positive perceptions and experiences when using SP in a DLE?
3. What are students' challenges when using SP in a DLE?

Research Design and Methods

Data were collected from two collaborative assignments, which were conducted in the DLE and required inquiries in the context of two virtual experiments using PhET simulations. The assignments were designed in collaboration with the physics teachers so that they were in line with the current topic and address SPs. When working in groups on the assignments, the students recorded their actions in the DLE using a screen-recording program. The discussions related to collaboration took place in chat messengers, which were also screen-recorded. Using screen-recordings as a part of dataset helps to examine the processes of creating and advancing knowledge, and learning unfolding in time. We study the observable elements of activities and actions (Damsa, 2010) and explore the nature of actions from three perspectives: access and use of digital resources, SP use, and collaboration. After the last assignment, students participate in a semi-structured interview. The interviews were analysed by thematic analysis means.

Preliminary Findings

The data was collected in the metropolitan area of Helsinki in the autumn of 2020, during the remote learning period. Altogether, 16 upper secondary first-year students participated in the study. The coding schemes were developed based on a literature review and through an examination of data (Toulmin, 1958; Durán, 2011; Thompson *et al.*, 2011). The coding scheme with main categories and some examples of actions is presented in Table 1.

Table 1. Coding scheme for screen-recordings with main categories and some examples of actions.

Category	Subcategory example	Action code examples
● **Access and use of digital resources**	Navigating between/ within resources	Navigating within resources provided by teacher Navigating within resources provided by others
	Use of digital resources	Experimenting/playing with the simulations Using computational software
● **Use of scientific practices**	Carrying out investigations	Make observations Take accurate measurements
	Interpreting data	Transform data in the form of graph/chart
	Developing explanations	Formulate a claim Present evidence and data Connect claim and evidence Formulate rebuttals
	Building and using models	Use a model to explain the phenomena Consider model limitations
● **Collaboration**	Conversation	Coordinate group process Confirm/accept
	Active learning	Request confirmation Request elaboration Elaborate
	Creative conflict	Doubt Offer alternative

RQ 1: General Patterns of SP Use during Collaborative Work in a DLE

The analysed data was visualized in a way presented in Table 2. Each dot represents a particular action code, the colour of the dot represents the code's category. Student's actions along the time are presented within one column. Each column is split in rows, representing consecutive 3-min episodes. The analysis showed that the use of SPs was preceded by in-depth reading or viewing of the resources and discussions. Students whose event sequences did not include SP use events demonstrated rich collaboration and were coordinating the group process. The experiment plans were written after the experiments had been conducted: students used the simulations by trial and error, until they obtained results, and then discussed how to make sense of these results and how to formulate the plan for the experiment.

Table 2. Visualized data of the first 15 minutes of one of the groups working on the assignment. The colours represent belonging to one of the code categories: ● Access and use of DLE; ● Collaboration; ● Scientific practices use.

Group 1, Assignment 2			
Time period, min	**Student 1**	**Student 2**	**Student 3**
0 - 3	●●●● (orange)	●●● (orange)	●●●●● (orange) ● (pink)
3 - 6	●●●●● (pink)	●● (orange)	● (pink)
6 - 9	● (pink) ● (green) ● (pink)	● (pink) ●●● (green)	● (green) ● (orange) ● (green) ● (orange) ● (green) ●● (pink)
9 - 12	●●●● (pink)	●●● (pink)	●●●●● (green)
12 - 15	●● (pink) ●● (green) ● (orange)	●● (pink) ● (green)	●● (orange) ● (green) ● (pink)

RQ 2: Positive Perceptions and Experiences when Using SP in a DLE

No preliminary findings so far.

RQ 3: Challenges when Using SP in a DLE (Screen Recordings)

Most observed challenges concern building models and developing scientific explanations. Most explanations included only the claim component; the reasoning component of scientific explanations was either missing or incomplete. The task 'develop a model' spurred discussions concerning the task objective. The inquiry was open, and students could model various phenomena from various perspectives; however, student discussions revealed a common belief in one and only one correct model. No group mentioned model limitations or provided rebuttals for their scientific explanations. Searching for information did not cause any challenges, although students faced challenges in synthesising information from various sources. None of the groups could come up with a plan for the experiment until they had spent a significant amount of time trying out the simulations and conducting experiments. In addition to the 'inverse' way of experimenting, we want to stress, that: 1) the plan for the experiment was formulated in a coherent scientific way only by groups that also read the texts on the topic before/after they conducted an experiment, thus connecting their experiences with existing models of phenomena, and 2) collaboration played a significant role in the iterative process of conducting an experiment.

Challenges when Using SP in a DLE (Interviews)

From the SP use perspective, the practice of developing models was perceived as the most challenging scientific practice. Nearly all students perceived using chat messenger as a challenge; however, in most cases the challenge of using the chat messenger actually concerned scientific communication and constructing explanations. Further analysis is being conducted.

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3.5 Mentor Group 5 | Sloten | 3.5.3

How Catchy are Eye-gaze Replays? A Qualitative Study Exploring the Use of Students' own Eye-gaze Stimulated Retrospectives in Organic Chemistry

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Keywords: Chemistry, Tertiary Education, Eye-Tracking, Self-Reflection

Focus of the Study

Learning organic chemistry requires the understanding of various complex representations and the respective implicit content they convey. Students, however, often struggle to derive the required information from an organic chemical representation to solve a problem (Talanquer, 2014). Their interpretation process is guided by salient or explicit features (*e.g.*, McClary & Talanquer, 2011), as well as single surface features (*e.g.*, Graulich & Bhattacharyya, 2017), or symbolic pattern recognition (*e.g.*, Weinrich & Sevian, 2017) and not as much by underlying implicit information and chemical concepts. Although numerous studies indicate that it is essential to focus on implicit properties and associated chemical concepts to draw conclusions about chemical properties or reaction mechanisms, there is a lack of instructions to support students in their visual and conceptual processing of organic representations (for review see Graulich, 2015).

As mental models are known to be constructed from explicit surface features (Schnotz, 2014), a highly promising approach for learning with complex organic representations might be to support learner's visual decoding process by guiding their visual attention to relevant domain-specific features of representations and to initiate a reflection process on one's own visual behaviour during a problem-solving process. By replaying one's own eye-gaze in a retrospective, the visual decoding process can be externalised (Zelinsky *et al.*, 2013) and could enhance student's self-reflection in order to critically evaluate one's own intentions, strategies and approaches. Therefore, the aim of this study is to investigate to what extent an eye-gaze-augmented retrospective in the context of organic chemistry problem-solving processes encourages learners to self-reflect and thus to, potentially, change their visual decoding process and performance. The results of this study could provide insights into how eye-gaze replays can be used in instructional settings and for developing adaptive learning systems in future technological applications.

Theoretical Background

The structure of an organic chemical molecule is commonly depicted as a symbolic-iconic representation (*e.g.*, Lewis structure). These representations contain explicit and implicit features of the chemical entities they represent (Hoffmann & Laszlo, 1991). To estimate properties of molecules or reaction processes a learner has to reason with implicit properties and associated chemical concepts. These implicit information are derived from inferences made from the explicit, visually decodable symbolic representation (Goodwin, 2010). While learning, the learner gradually constructs a mental model of the given representation. At first, the learner constructs a visual internal representation via visual feature analysis of the visual pattern of the pictorial information. In the next step, the learner constructs a mental model via structure mapping of selected information and use of prior domain-knowledge (see Figure 1) (Schnotz, 2014).

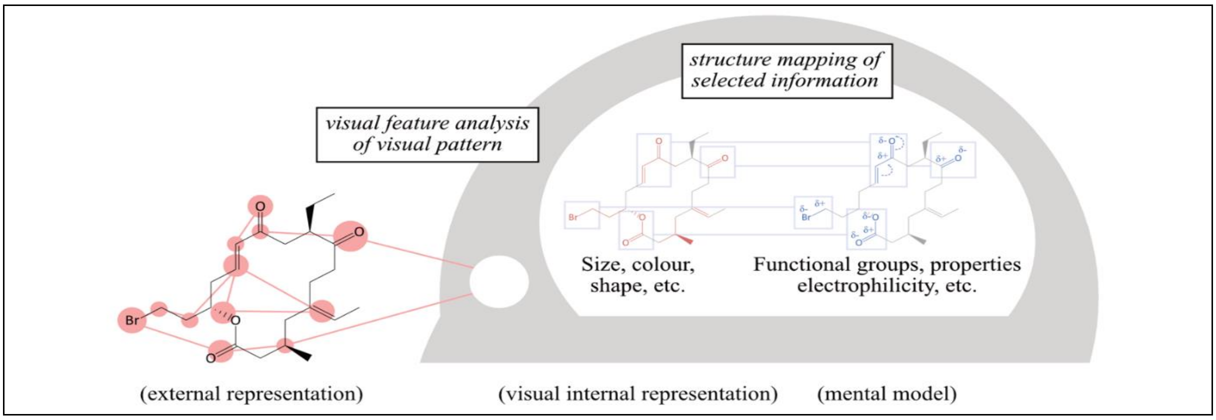

Figure 1. Illustration of a mental model construction.

Thus, to understand a representation, learners need to know how to guide their eye-gaze to relevant domain-specific features rather than to salient, but irrelevant features to avoid constructing erroneous mental models. Many studies report that organic chemistry students widely rely on salient features of organic chemical representations, leading to multiple difficulties in problem-solving (*e.g.*, Graulich & Bhattacharyya, 2017; McClary & Talanquer, 2011; Weinrich & Sevian, 2017). Instructional designs that aim at supporting students in selecting relevant elements from irrelevant ones, like example-based learning (for review see van Gog & Rummel, 2010), highlighting (for review see Richter *et al.*, 2016) or eye-movement modelling examples (for review see Xie *et al.*, 2021), have been reported in cognitive psychology. However, addressing the individual needs of learners with such instructional designs could be challenging. Van Gog *et al.* (2005) demonstrated that retrospectives cued with one's own eye movements were able to uncover facets of the problem-solving process in physics tasks. Since metacognitive abilities have a major impact in learning with representations (Gilbert, 2005), using a learner's own eye-gaze replay as a cue for self-reflection about their problem-solving process could be a promising approach. First attempts using an eye-gaze-augmented retrospective were carried out in debriefing situations in medical simulations and showed highly promising results (Szulewski *et al.*, 2018). Although this approach seems to be promising and highly suitable for complex visual representations commonly used in organic chemistry, the influence of an eye-gaze-augmented retrospective to stimulate students' self-reflection in chemistry have not been explored so far.

Research Questions

In order to investigate to what extent an eye-gaze-augmented retrospective in the context of organic chemistry problem-solving processes can be used to encourage learners to self-reflect and thus change their visual decoding process and performance. The following research questions arise:

1. How can student's visual and conceptual processing be characterized when students are cued to reflect on their own eye-gaze replay?
2. To what extent is students' retrospective and performance in problem-solving influenced by the type of task (*i.e.*, visually and conceptually demanding)?
3. To what extent do students change their decoding process (differences in eye-gaze patterns) as the result of exposure to their eye-gaze replay and does it affect their performance?

Research Design and Methods

To address the research questions, the eye-gaze-augmented retrospective embedded in an instructional setting in organic chemistry education is explored primarily qualitatively with beginners in organic chemistry (about 50 in total). The retrospection is structured similar to the reflection model of Korthagen (1985). After an initial problem-solving, the learners look back and become aware of their approach and then reflect on alternatives and strengthen successful approaches. Afterwards, a similar task is solved again. Therefore, the participants in this study are prompted 1) to solve an organic chemistry task with a complex representation (recorded with the eye-tracker), 2) to watch their eye-gaze replay of their problem-solving process and are purposefully interviewed about their problem-solving behaviour, 3) to compare their eye-movements and their response with the task solution to identify irrelevant and relevant elements and to reflect on their decoding strategies and conceptual resources, and 4) to solve a similar task again (as well recorded with the eye-tracker). In total, the participants work on three different task sets, which differ in the level of visual and conceptual demands. Additionally, participants are prompted to rate their perceived self-confidence, task difficulty, cognitive load, and visual and conceptual demand of each task, as well as, their abilities in organic chemistry before and after the study on a bipolar scale.

The collected data will be analysed qualitatively with an emphasis on students' visual and conceptual processing. The interview recordings will be transcribed and analysed using qualitative content analysis (Saldaña, 2016). Eye-tracking data will be analysed using various metrics (*e.g.*, time to first fixation) and pattern analysis (Tang *et al.*, 2018). Triangulation of these data could reveal how visual and conceptual processing interplays and how a specific eye-gaze pattern is linked to productive or unproductive problem-solving. Additionally, the data analysis allows to characterize what features of their own eye-gaze replay students use to reflect on their approaches. The analysis aims at an intrapersonal comparison of changes in the problem-solving behaviour and performance.

Preliminary Findings

The data collection is currently taking place until summer 2022 and will be completed before the start of the ESERA summer school, so that ideally feedback from the summer school can be incorporated into the data analysis.

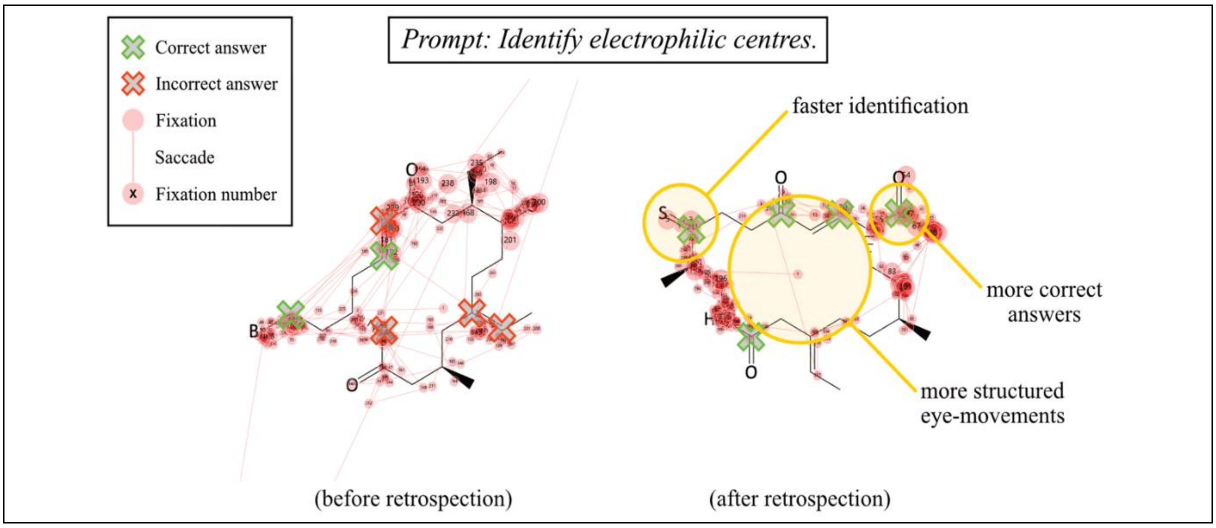

Figure 2. Comparison of the problem-solving process (as a gaze plot) before (left) and after (right) the eye-gaze-augmented retrospective.

After a first brief scan of already collected data, it is possible to assume that the eye-gaze-augmented retrospective stimulates the participants' self-reflection on their problem-solving process. The instruction points out visual and conceptual gaps and encourages the participants to change their visual behaviour and performance (see Figure 2). Furthermore, the participants' ratings of their abilities in organic chemistry changed after the eye-gaze augmented retrospective, which could be an indication that the instruction helps the participants to become aware of their individual knowledge gaps. Based on the results of this study, additional implications on how to develop an eye-gaze-based adaptive learning system will be drawn.

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3.5 Mentor Group 5 | Sloten | 3.5.4

Novice Science Teachers' Appropriation of Teaching that Capitalizes on Students' Thinking

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Keywords: Science, Secondary Education, Teacher Education, Pre-service Teacher Education, Practice-based Teacher Learning

Focus of the Study

Pedagogies of delivery, which feature teacher practices designed to supply students with content knowledge and then verify students' successful reproductions of that content, are common in classrooms (Banilower *et al.*, 2013; Roth *et al.*, 2006). Educational reforms emphasize that science teaching should extend beyond rote memorization and routine procedures common in delivery pedagogy, and instead provide opportunities for rigorous learning as students participate in and develop deep and meaningful understandings of the knowledge-building practices and disciplinary content of science (NRC, 2012). Multiple lines of research have identified that pedagogies suitable for achieving the goals of reform capitalize on students' thinking as resources to drive rigorous science instruction (*e.g.*, Elby *et al.*, 2014, Windschitl *et al*, 2012). But even where reform-oriented pedagogies are emphasized in teacher preparation programs, supporting novices to adopt such pedagogy remains challenging for teacher educators and educational researchers (Thompson *et al.*, 2016; Stroupe, 2016). Understanding how novice teachers can be supported to develop a teaching practice centered on capitalizing students thinking, and to continue adopting that practice in their beginning teaching contexts, remains a critical area of research (Braaten & Sheth, 2017; Stroupe, 2021) This study explores how novice teachers orient to the role of students' thinking in instruction as they engage in practices to plan, enact, and reflect on teaching, and their appropriation of teaching that capitalizes on students' thinking.

Theoretical Framework

This study of pre-service science teachers' (PSTs) development of practice draws on literature about PSTs' learning within and from the conceptual and practical underpinnings of teaching practice that capitalizes on student thinking (Grossman, 1999; Lampert & Graziani, 2009; Thompson, Windschitl, Braaten, 2013). Of importance in practice-based teacher education is the role of conceptual tools (*e.g.*, frameworks, principles, knowledge about learning) and practical tools (*e.g.*, tools, practices, instructional resources) as sites of learning which can mediate PSTs' development of practice (Grossman, 1999; Greeno & Engestrom, 2014). Through engagement with the conceptual and practical tools of teaching, novices can appropriate the conceptual and practical underpinnings of teaching that capitalizes on students thinking to achieve deeper and more meaningful understanding (Grossman, 1999).

Teaching that capitalizes on students thinking involves drawing out and attending to student thinking by creating opportunities for students to share their thinking, assessing the how and why of shared thinking to identify resources that can further teaching and learning, and advancing students' understanding by crafting responses that advance students' thinking (Levin, Grant

& Hammer, 2012; Gotwals & Birmingham, 2016; Kang & Anderson 2015). Conceptually underpinning the teaching practice of attending, assessing, and advancing students thinking is an orientation towards students' ideas as the raw material of learning, using students' ideas, experiences, and culture as critical resources to guide instruction (Hammer & van Zee, 2004; Coffey *et al*., 2011; Larkin, 2012).

While teaching that capitalizes on students' thinking is motivated by an orientation to student thinking as resources, the constituent practices of this pedagogy may be employed with an orientation to students' thinking as obstacles to understanding, seeking to disrupt and replace students' thinking with *correct* ideas (Larkin, 2012). Prior research suggests that novices' orientations to the role of students' thinking to drive instruction might play a role in whether and to what extent PSTs appropriate teaching practice that capitalizes on students' thinking (Stroupe, 2016; Tekkumru-Kisa *et al*., 2022). But there remain gaps in our understanding about how the tools and practices central to PSTs' learning to capitalize on students' thinking can support their learning, and how these tools might foster appropriation of conceptual and practical underpinnings of such practice as PSTs transition into teaching.

Research Questions

These research questions attend to PSTs' orientations as they interacted with tools and practices which embodied the practical and conceptual underpinnings of attending, assessing, and advancing students thinking in a university teacher preparation course, and their appropriation of the practical and conceptual underpinnings of that practice as they planned and enacted instances of drawing out students' ideas in their first full time teaching internship following the methods course. I ask:

1. How did PSTs orient to students' thinking as they:
   a. planned for, rehearsed, and reflected on a science lesson in their final methods course?
   b. planned, enacted, and reflected on teaching in their first full-time teaching internship?
2. How did PSTs appropriate the practical tools for and conceptual underpinnings of eliciting, assessing, and using students' thinking in their first full time teaching internship?

Research Design and Methods

This study investigates the learning of five PSTs by focusing on their experiences within the context of a practice-based university final methods course (called herein "Teaching to Capitalize on Student's Thinking" (TCST) and their first full-time teaching internship contexts which occurred the following semester.

To address the first research question, I will draw on Larkin's (2012) framework to understand how PSTs oriented to the role of student thinking in each context as they engaged in lesson planning, enactment, and reflections. I will analyze PSTs' written work on carefully-designed planning and rehearsal tools and videos of rehearsal instruction, and interviews about PSTs planning and rehearsing to understand their orientations to student thinking as they interacted with conceptual and practical tools of teaching. To understand their orientations in their internship teaching, I will examine their orientations to student thinking evident in pre- and post-interviews with PST about the lessons that they taught and in observed instruction.

To address the second research question, I will employ an appropriation framework (Grossman, 1999) to analyze PSTs' internship teaching to understand whether and how PSTs appropriated the practical and conceptual tools with which they engaged in the TCST. At the time of data collection, I used an instructional quality assessment (Tekkumru-Kisa *et al*., 2021) to characterize teachers' use of practices in the design and observed enactment of teaching and provide some insights about their appropriation of practical tools. Teacher interviews conducted before and after each of their observed internship lessons inquired about their use of conceptual and practical tools from the TCST, and provide insights into their intended and desired teaching practices. Adapting Grossman's (1999) framework for appropriation (Tekkumru-Kisa *et al.*, 2022), these data will provide insights about the degree to which PSTs appropriated the conceptual and practical underpinnings of teaching to capitalize on students' thinking by examining the alignment of their language about using the conceptual and practical tools central to the TCST, and their conceptual explanations of and reasoning about their intended and enacted practices relating to drawing out students' thinking.

Preliminary Findings

Data was collected in Fall 2020 (TCST data) and Spring 2021 (Internship data). Analyses of these data will commence in Summer 2022.

This study draws on research which suggests that the orientations to student thinking that novices take up in their beginning teaching contexts are important in their development of pedagogy suitable for the goals of reform (Larkin, 2012; Stroupe, 2016). Contributing to the current gaps in understanding about how to support novice as they transition to their beginning teaching contexts, this study seeks to investigate the orientations to student thinking taken up by novices as they planned and enacted teaching in a practice-based teacher education course which utilized tools, routines, and practices endemic to planning and enacting rigorous instruction as a site of learning, and in their beginning teaching contexts. Understanding these orientations in concert with teachers' appropriation has the potential to provide new insights into how teacher education contexts can better support novice teachers' learning to capitalize on students' thinking.

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3.5 Mentor Group 5 | Sloten | 3.5.5

Teacher Professional Development in Elementary Science Education – Exploring the Intersections of Inquiry-based Science Practices, Collaborative Structures, and Identity Development

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Keywords: Inquiry-based Science Education, Elementary Education, Teacher Leaders, Professional Development, Identity, Transdisciplinarity

Focus of the Study

This study focuses on elementary in-service teachers' professional development for science education, with a focus on science teacher identity development. In particular, the research examines the ways in which co-teaching and co-development mediate in-service teachers' identity-related perspectives as they learn about teaching science through inquiry. The research is situated in the European country of Luxembourg, and the context is a Resource Center dedicated to supporting the teaching and learning of science at the elementary levels. In particular, this study focuses on an initiative for teacher education in which classroom teachers codevelop and coteach professional development workshops together with university researchers. The Center's Teacher Leader Network is a group of primary school teachers and science education specialists that collaborate to develop innovative science education resources for elementary teachers. Inquiry-based science education offers both teachers and students a space to engage in science in an open and scientific way (meaning "doing" science), and to support and further develop literacy, through talking about phenomena and curiosities. In Luxembourg's multilingual setting, constructs of plurilingualism and interdisciplinarity are especially relevant to this study.

The central object of this study is to investigate the role of collaborative structures for mediating teachers' identity-related professional development. As such, the project works towards case studies focusing on their teaching practice and experiences, collaboration with the researchers and with each other, processes of co-development of in-service teacher workshops and the co-teaching of the workshops.

Review of Literature | Theoretical Background | Theoretical Framework

A small group of teachers participate in the Teacher Leader Network, meeting monthly either at the Center, or remotely in response to covid19 restrictions, with the goal of collaboratively developing teacher education modules for future dissemination at the Center. Participants learn about theories of inquiry-based science and share experiences teaching science at elementary school. This study is grounded in cultural studies theoretical perspectives, positioning processes of learning and knowing as embedded in socially-, culturally- and historically-framed practices (Sewell, 1999; Bourdieu, 1982; Schutz, 1967). Being and becoming teachers of science is an emergent and ongoing process, and through a community-of-practice model, participants learn about innovative practices for teaching science through co-planning of workshops that they themselves then later co-teach with Center team members. As collaborating teachers learn new strategies and content for the teaching of science, they collaborate on learning about teaching practices for inquiry-based science (Siry, 2011). The structure of the teacher leader network works towards a combination of learning about science, learning about teaching, and becoming a member of a community of practice (as newly integrated teacher educators). Coteaching is being co-present and generating dialogue about shared experience, and coteaching focuses on learning to teach at the "elbow of another" (Tobin & Roth, 2006). In short, coteaching assumes that *teaching is a sociocultural activity* in which participants learn to teach by teaching together.

Research Questions

This research project is a case study that examines the professional development and identity development of in-service primary teachers as teacher leaders for inquiry-based science learning during the past three years (2020-2022). Several questions have emerged to guide the analysis, in seeking to understand what the concept of teacher leader in inquiry-based science education offers to teacher professionalization. The overarching question that provides a guide to the research is how does the process of in-service teacher professional development emerge and evolve in the context of coteaching? In seeking to understand how the structure of the teacher leader network impacts identity and supports becoming and being a science teacher, several questions come together through ongoing analysis, including: How does the practice of teacher leaders develop through the structure of the initiative? What are challenges and advantages? How can teachers be taught? What are the structures to support inquiry-based science teaching and how can they be developed? And last but not least – How does ownership, agency and engagement transform or remain stable within the given settings?

Research Design and Methods

The goal of this study is to better understand teacher learning for science, in order to continue to support professional development. The participants in this study are the members of the Center team, who each hold different professional roles, and come together once a week to support the work of the Center as collaborating teacher educators. The PhD research is embedded into a larger study that seeks to provide windows into participants' roles, positions, and perspectives throughout evolving collaborations as teacher educators. This component of the research focuses specifically on the identity-related ways in which teacher-participants engage in the Teacher Leader Network, and the ways in which the project impacts their identity-related perspectives on science teaching and learning. The data corpus includes four types of data resources, 1) videos of weekly team meetings, 2) artifacts developed to support teacher education workshops (slides, handouts, etc.), 3) videos from focus group discussions and 4) reflective journal entries.

Event-oriented inquiry (e.g., Tobin & Ritchie, 2012) serves as an analytic tool to narrow and deepen the research focus and highlight moments that are central to participants' learning. Event-oriented inquiry is grounded in an understanding that the analysis of social systems needs to be examined relative to the "cultural enactment" of events (Tobin & Ritchie, 2012, p.118). These events are structured by the material, social, and cultural resources on hand, which also mediate the structuring of future events. Analysis for this research emerges from participatory collaborative research and teaching structures, in which we first collectively identify central events, and then utilize methods from video-ethnography (Pink, 2013) to examine overarching themes that emerge within this event as related to professional development processes and process of being and becoming teachers of science. Critical ethnographic approaches guide the research (Carspecken, 1996) which allows for linking the research to larger social structures. To allow values and worldviews to become recognized in the research, following critical ethnography supports overcoming the status quo in educational research, as "critical ethnography and critical genres of research (…) challenge the separation of values and politics from “knowledge”” (Carspecken, 2005). In particular it allows for analyzing complex situations through critical theoretical frameworks, while applying a range of approaches and leaving space to creativity, e.g. teacher identity, which is fluid and complex (Avraamidou, 2014).

Preliminary Findings

Several preliminary findings are emerging from this research, which can be expected to be refined further by the time of the ESERA summer school. Through a recursive, iterative analysis, with participants, three claims are evolving, as follows: Shared responsibility shapes construction of participants’ identities as new teachers; Group development of lessons and opportunities for critical dialogue are important resources for identity formation; Supported opportunities for coteaching can lead to the development of a community of practice. These will be refined over the next months, as I will engage in focus group discussions with the participants, focused on discussing their experiences after co-teaching their workshops this spring. As the group experienced a concrete situation in a different context it will be engaging to bring their expertise, experiences, ideas, and values together. And then the themes, data, and theory will be brought together.

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3.5 Mentor Group 5 | Sloten | 3.5.6

Implementing the Science Capital Teaching Approach in a Scientist-facilitated, Informal Intervention

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Keywords: Science, Primary Education, Out of School Education, Science Capital, Informal Science Education, Public Engagement, Science Communication, Children's Perception of Scientists, Children's Attitudes towards Science

Focus of the Study

There is a need to generate research evidence to improve educational practice in science in Ireland, particularly in Informal Science Education (ISE) (DES, 2017). ISE is defined here as science engagement and learning that operates outside of the formal school curriculum (Eshach, 2007). This work aims to contribute to best practice in facilitating ISE activities by investigating how science capital-based pedagogical techniques, implemented in a hands-on, scientist-facilitated intervention, supports the development of children's science capital.

Science capital is a methodological and empirical construct that encapsulates all science-related knowledge, attitudes, experiences and social contacts that a person may have (Archer *et al.*, 2015). Briefly, the more science capital a person has, the more likely it is that they will engage in science-related activities. Existing work on science capital aims to widen participation and improve inclusivity in STEM.

Many ISE programmes aim to increase participation in science by increasing interest, however interest alone does not predict participation (Godec *et al.*, 2017). Though children generally have positive views of science (Shimwell *et al.*, 2021) many, especially those from underrepresented backgrounds (Archer *et al.*, 2015), cannot envision themselves as scientists or as someone that does science-related activities (DeWitt & Archer, 2017). There is a need to improve ISE practices and remove participation barriers so that wider range of young people can see why science could be for them. The social justice approach embedded in the Science Capital Teaching Approach (SCTA) focuses on removing these barriers (Godec *et al.*, 2017). This is a shift away from the traditional aim of ISE, which was to change the individual by increasing interest in science, rather than adapting STEM to be more inclusive.

This research will investigate whether implementing this approach in an informal short-term, scientist-facilitated intervention is effective. As most scientists do not have teaching training, they lack the general teaching techniques and rapport that teachers have with their pupils. Science communication training programmes addressing these issues are limited. A key aspect of implementing the SCTA in this intervention is to establish both an intervention format and facilitator-specific training, that will enrich pupils' science capital by identifying their individual funds of knowledge, valuing their contributions, and not perpetuating misconceptions.

Review of Literature

While the Irish public generally considers science to be important, the public's perception of what is science and what type of people are scientists is narrow (SFI, 2020). These perceptions need to be challenged so that people feel comfortable engaging with science. Changing the

STEM field to become more equitable by removing participation barriers is therefore becoming a key objective for ISE practitioners interested in increasing diversity of participation in long-term engagement with STEM from a young age. As with participation in the science classroom, lack of participation in ISE was found to be related to social and economic barriers, and the nature of the ISE environments themselves, rather than a lack of interest among young people (DeWitt & Archer, 2017; Godec *et al.*, 2021).

ISE, when done well, can give young people the opportunity to learn about science in a way that is more closely related to real world contexts (Bell *et al.*, 2009). It is essential that ISE programmes, whatever their length, contribute to the same endeavour and ensure that they are promoting awareness of a range of STEM careers and showing a diverse cohort of scientists. The image of scientists as "white", "male", "old" and "brainy" is alive and well (DeWitt *et al.*, 2013; Hillman *et al.*, 2014; Shimwell *et al.*, 2021). Thus, it is important for ISE experiences to broaden this image to include a wider range of scientists and to emphasise a broader set of characteristics that scientists have (Shimwell *et al.*, 2021).

This research will be underpinned by the theoretical framework associated with 'science capital', described previously, and also used in the SCTA (Godec *et al.*, 2017). The SCTA was originally developed for the formal teaching context, emphasising the development of rapport between teachers and students to personalise and localise science lessons. Employing the SCTA in the formal classroom helps to improve student engagement, leads to participation by more diverse individuals and positively contributes towards participants' science capital (Godec *et al.*, 2017). However, little is yet known on how SCTA might be applied within programmes of the sort run by many ISE providers, including short-term brief interactions between scientists and young people.

While participation in science education is relevant for generating a diverse STEM-literate future workforce (Archer *et al.*, 2020), it is just as important for young people in their everyday lives. Feeling comfortable engaging with science throughout their lives will enable people to actively participate in and shape the future (Archer, 2015; DES, 2017).

Research Questions

Central Research Questions

1. What does the SCTA look like when implemented in a hands-on scientist-facilitated and brief informal science intervention?
2. How, if at all, does the SCTA support children's science capital when implemented in a hands-on scientist-facilitated informal science intervention?

Aim

Explore the proximal outcomes of hands-on scientist-facilitated intervention, 'Fantastic DNA', which draws on the SCTA, related to children's science capital.

Specific Objectives

- Conduct a pre-post single cohort study design using a hands-on science workshop as an intervention.
- Investigate the potential contribution towards supporting children's science capital.
- Identify which pedagogical elements of the intervention had the greatest effect (if any) on supporting pupils' science capital, specifically their perceptions of scientists and their own science-related attitudes and dispositions.

Research Design and Methods

Research Design

A pre-test post-test mixed-methods single cohort study design will be used (Figure 1).

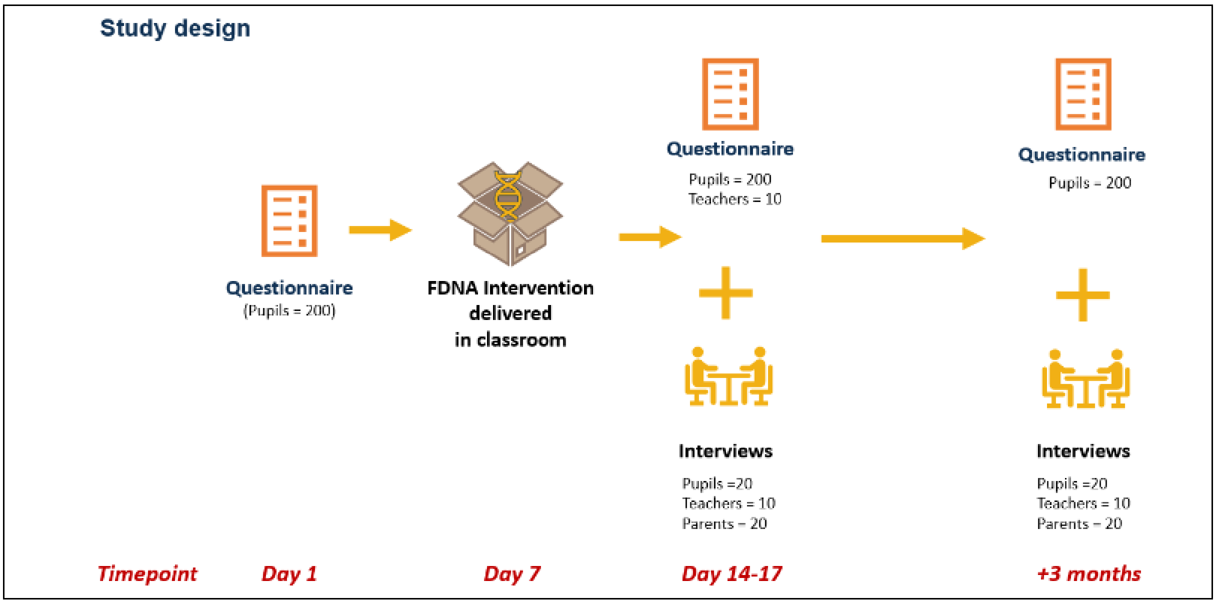

Figure 1. Schematic representation of study design.

Intervention

"Fantastic DNA", an established and evaluated intervention, is an example of a scientist-facilitated hands-on session. Children extract DNA from a banana, in small groups under the guidance of a scientist explainer. This intervention, delivered online during the COVID19 pandemic, has recently been updated to integrate the SCTA, in particular; knowing someone in a science related role, science-related attitudes, values and dispositions and knowledge about the transferability of science. The session will be re-adapted to in person now that COVID-19 restrictions have lifted.

Research Sampling

Participants will be recruited by convenience sampling by inviting schools who request school visits from the research group's outreach team to participate.

Methodology and Methods

The mixed-methods approach will utilise questionnaires and semi-structured interviews. This mixed-methods approach will allow investigation of the "what" (quantitative) and the "how" (qualitative) (Cohen *et al.*, 2017). Qualitative data will provide richer context to understand the quantitative data. Questionnaires will be collected from all consenting children. Interviews will be conducted with a smaller cohort of pupils, teachers and parents.

Instruments

Questionnaires and interview questions will be derived from existing instruments used in the evaluation of Fantastic DNA, adapted and piloted before being used in the main study.

Questionnaires:

- Children (pre- and delayed post): to assess aspects of science capital, including interest in and enjoyment of science, knowledge about life as a scientist, perceived competence in science and science-related aspirations.

- Teachers (post-intervention): to gather perceptions of any potential outcomes related to children's classroom engagement and aspects of science capital.

Interviews (post-intervention):
- Children: to explore their perceptions of the intervention, their science capital and any potential outcomes.
- Parents: to investigate any post-intervention differences in science engagement at home (e.g. science-related conversations).
- Teachers: to further explore any perceived outcomes related to children's engagement with science and their science capital.

Data Analysis

A combination of statistical techniques will be used. Descriptive statistics will give an initial indication of any changes following the session. Exploratory Factor Analysis may be used to improve understanding of the complex problem by clustering variables. ANOVA and regression analysis will be used to investigate relationships between variables. Qualitative data will be explored through comparative analysis and analysed using deductive and inductive approaches.

Preliminary Findings

A pilot of the intervention, Fantastic DNA in a Box, was run by the research group in June 2021. This intervention is a remotely facilitated version of the in-person classroom intervention, Fantastic DNA, that I will use in my study. This session was revised to incorporate the SCTA and adapted to restrictions incurred by the COVID-19 pandemic. The pilot also employed a single-cohort pre-post study design, minus a delayed post-questionnaire. Pre- and post- questionnaires were collected from pupils (N = 175). Interviews were done with pupils (N = 14), parents (12) and teachers (N = 8).

The aims of this study were to assess children's perception of scientists and whether participation in the intervention had any impact. Evaluation data collected are currently being analysed. The results of this analysis will be used to identify areas in the session that should be adapted for in-person and ways in which the methodology should be revised to further disentangle and address certain findings. The findings will be presented at the ESERA summer school.

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3.5 Mentor Group 5 | Sloten | 3.5.7

Investigation of a Digital Learning Environment in the Productive-Failure-Setting for Chemistry Learning

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Keywords: Chemistry, Secondary Education, Productive Failure, Problem Solving, Instruction, E-Learning, Conceptual Change

Focus of the Study

In recent years, *Productive-Failure-Setting* have received increasing attention due to the positive development of conceptual understanding compared to classical learning approaches (Kapur & Bielaczyc, 2012; Loibl & Rummel, 2017). These learning approaches include an initial problem-solving task and end with an instruction phase (problem-solving-prior-to-instruction, PS-I, Kapur & Bielaczyc, 2012). So far, this approach has been mostly replicated in mathematics and partly adapted in physics (Wille, 2019). These studies are based on the teaching example of the *Productive-Failure Setting* from mathematics by Manu Kapur (2010).

In chemistry there are only few studies deal with the use of the PS-I. Therefore, this PhD project aims to adapt and investigate the PS-I approach as a teaching design for the field of chemistry and generate a chemistry-specific example of this learning approach.

The adaptation of the *Productive-Failure-Setting* and the generation of the example will be done on a learning-management-platform (ILIAS) to ensure easier accessibility. In the course of this, the teacher-led instruction in digital PS-I is dropped and must be adequately replaced. For this purpose, it will be examined whether a digitally and medially prepared conceptual-change-text (Beerenwinkel, 2016) is suitable.

Theoretical Background

Productive Failure

In Manu Kapurs (2010) learning concept *Productive-Failure* (PF), a problem-solving task is placed in front of an instruction (PS-I: Kapur & Bielaczyc, 2012; Loibl & Rummel, 2017), i.e., the logic of classical learning approaches is reversed (instruction-prior-to-problem-solving, Kirschner, Sweller & Clark, 2006). Learners are confronted with a problem-solving task for which they do not yet have a viable scientific concept (Kapur, 2010; Kapur & Bielaczyc, 2012). The learners are left uncertain about correct solutions. This experienced uncertainty is therefore referred to as *failure* (Hundertmark, 2021). This is followed by the instruction phase, in which the necessary concepts for solving the problem-solving task are taught by incorporating the learners' conceptions or created learners' solution sketches. In the productive failure setting, learners must be involved in the learning design, which includes four central, interdependent mechanisms (Kapur, 2010; Kapur & Bielaczyc, 2012): (1) activation and differentiation of the previous knowledge with regard to the desired concepts, (2) attention to typical learners' solution sketches or learners' conceptions of the desired concepts, (3) explanation and elaboration of these solutions or learners' conceptions and (4) organization and compilation of the typical solution sketches to the approaches to the desired concepts.

The previous study on *Productive-Failure* in chemistry learning (Hundertmark, 2021) show that the positive effect, which is also confirmed in various studies in learning mathematical concepts (Loibl & Leuders, 2018; Loibl & Rummel, 2014; Kapur, 2014), can be replicated for learning chemical concepts. This means that this instructional design improves conceptual understanding and transfer in chemistry.

Conceptual Change Text

One approach working with learners' conceptions are concept-change-texts (Beerenwinkel, 2006; Guzzetti *et al.*, 1997). This type of text represents a teaching-learning material that deliberately addresses alternative learners' conceptions that are refuted against the background of scientifically recognized conceptions. In this way, learners are specifically instructed to expand on their previous conceptions, thus undergoing a conceptual change toward scientifically adequate conceptions (Egbers & Marohn, 2013).

Research Questions

1. To what extent does the developed problem-solving task meet the conditions for a *Productive-Failure-Setting*?
2. To what extent are the learners' solutions sketches to solving problems picking up in the instruction phase?
3. To what extent can the classical teacher-led instruction phase be replaced by a digital conceptual change text?
4. To what extent do learners of the traditional PS-I group show a greater development in their conceptual understanding than learners of the digital PS-I group?

Research Design and Methods

A previously created e-learning-unit (ILIAS-unit about dissolution processes and intermolecular interactions) serves as a basis for the survey of the learners and is adapted if necessary.

In the first phase, the digital-learning-unit is reviewed and further developed in the *Productive-Failure-Setting*. To answer the research question RQ1 – RQ2, the student performances are analyzed with the help of their solution sketches and semi-structured interviews (Niebert & Gropengießer, 2014) with the method of thinking aloud (Sandmann, 2014). In RQ1, special attention is paid to the complexity of the problem-solving task. The learners should invent solution sketches without solving the problem canonically if possible. Previous studies have shown that this design feature is important in order to promote the activation of prior knowledge (Kapur & Bielaczyc, 2012; Loibl et al, 2017). Taking up on learners' solution sketches during the instruction phase promotes learners' awareness of the limits of their knowledge and the recognition of the scientifically accepted concepts (Loibl & Rummel, 2014a; Loibl et al, 2017). For this reason, the data collected from the interviews and solution sketches are used to verify whether the learning unit picking up student performance.

In the second phase, the use of an e-learning-conceptual-change-unit will be compared to the teacher-led instruction to check whether a digital-conceptual-change-text is an adequate replacement for the teacher-led instruction. In order to be able to answer RQ3, two comparison groups (PS-I with teacher-led instruction phase and PS-I with digital-concept-change-unit) are formed. By means of quasi-experimental design, the concept understanding is collected by pre- and post-test to assess the effectiveness.

To be able to make a final statement as to whether the use of a digital-learning-unit in the *Productive-Failure-Setting* is viable, two comparative groups (traditional PS-I and digital PS-

I) are formed again and the learners' understanding of the concept is determined by means of pre- and post-test.

Preliminary Findings

When the ESERA Summer School takes place, the following results can be presented:

- Evaluation results from the solution sketches and the interviews of the first phase (RQ1-RQ2).
- Hopefully, an adapted digital-learning-unit in *Productive-Failure-Setting* (RQ1-RQ2).

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3.6 Mentor Group 6 | Grachten | 3.6.1

Applying the Lens of Science Capital to Understand Student Engagement in China

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Keywords: Science, Secondary Education, Out of School Education, Science Engagement, Science Capital, International Comparison, COVID

Focus of the Study

This research seeks to determine the validity of the science capital concept and its applications in understanding students' aspirations and engagement with science in the context of mainland China. This research will examine the level of science capital among Chinese pupils aged 15 years old and explore whether their science capital scores do, or do not, correlate with their level of engagement with science. The theoretical bases of science capital and the pedagogical approaches relating to this concept will be critiqued in light of the findings. Where appropriate, conceptual mismatches will be highlighted, and revisions to the theory will be proposed. By taking this approach, it will be possible to compare the UK and Chinese context and to explore the implications for educators and policy makers working in education in China and in the education of Confucian-culture students in the West. Due to the timing of the research, the extent to which COVID-19 has impacted on students' science capital and subsequent engagement with science will be also discussed.

Review of Literature | Theoretical Background | Theoretical Framework

Science capital is a relatively new theoretical framework developed from a longitudinal research project (ASPIRES) on UK students' aspiration to science careers (Archer, *et al.*, 2013). Based on the analysis of over 19,000 surveys, Archer and her team found that pupils' science aspirations had a strong correlation with their families' cultural capital, especially the science-related resources provided by parents (Archer, *et al.*, 2014). In order to clarify these science-related resources, Bourdieu's (1986) classic social reproduction theory was extended to develop the framework of 'science capital'. Archer and colleagues thus conceptualized science capital as "a conceptual device for collating various types of economic, social and cultural capital that specifically relate to science—notably those which have potential to generate use or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science" (Archer, *et al.*, 2015, p. 5).

Using the conceptual tool of science capital, the Enterprising Science project examined the ways in which young people with different backgrounds engage with science and how these engagements are supported (King's College London, 2013). Utilising data from ASPIRES, and classroom observation data from Enterprising Science the researchers argue that low science capital can limit pupils' opportunities and outcomes in life, and is key in explaining why students do not continue with STEM learning and related careers (Godec, *et al.*, 2018; DeWitt, *et al.*, 2016).

As a research tool explaining young people's science engagement, science capital has been validated within UK classrooms and some informal learning contexts (DeWitt, *et al.*, 2016;

Archer, *et al.*, 2014). However, with the view to refining this concept and to making it a more of a universal tool, the theoretical framework needs to be tested in different education systems and with a wider age range. An international validation and comparison, therefore, will make a valuable contribution to theory, policy and practice.

There are many gaps in our understanding related to young people's perceptions of science in China. According to PISA 2015, 15-year-olds from four big cities in mainland China show the highest performance among 69 participating countries and economies (OECD, 2015). Conversely, PISA 2015 also indicates that only 16.8% of participants have science-related career expectations, which is much lower than OECD average (24.5%) (OECD, 2015). Although there is a notable gap between their high academic performance and relatively low interest in science career, few studies discuss Chinese students' engagement with science. Therefore, using the tool of science capital to examine student engagement will offer new, and arguably much needed, insights into understanding the Chinese educational landscape, especially with respect to gender and socioeconomic status.

Furthermore, it is significant to note that the data were collected one year after the outbreak of COVID 19. As a global topic closely related to medical and scientific issues, it seems reasonable to assume the pandemic impacted students' engagement and aspirations to science in some way. For example, UK research found that young people are now more interested in a scientific career as a result of COVID 19 (British Science Association, 2020). Given that China originally reported the pandemic, it seems likely that Chinese students' science-related engagement and perceptions will have also been impacted. Thus, science capital arguably has potential as a useful tool to understand how Chinese student's engagement and aspirations changed before and after the global pandemic.

The main and the most important theoretical framework to be used is the concept of science capital (DeWitt, *et al.*, 2016). As discussed above, science capital extends Bourdieu's social reproduction theory (Bourdieu, 1986) and uses the concepts of habitus, field, capital to explain how students' backgrounds affect their engagement in science. In addition to the theoretical concept of science capital, other theories explaining student engagement with science will be used. For example, Osborne *et al.*'s (Osborne, *et al.*, 2003) review documenting attitudes towards science will help with understanding pupils' academic choices. Other frameworks, including Carlone *et al.*'s (2014) work on science identity and Hampden-Thompson and Bennett's (2013) theorizations of emotional and cognitive engagement will also be helpful in developing a rich understanding of factors affecting students' views and behaviour. Last but not least, and due in part to the limited number of papers examining the situation in China, studies focusing on young people from Confucian-heritage immigrant families will be important in providing appropriate contextual information. Woodrow (1996), for example, found that Asian students are highly influenced by their families, who emphasize long-term success instead of personal enjoyment and interest. The extent to which this is similar in China will be clarified during the course of the proposed research.

Research Questions

1. Is the concept of science capital concept and its applications an appropriate framework for understanding students' aspirations and engagement with science in the context of mainland China? How does the Chinese situation compare with prior findings from the UK?
2. How do social inequities in Chinese secondary education affect students' science engagement?
3. To what extent has the outbreak of COVID-19 had an impact on students' science capital and subsequent engagement with science?

Research Design and Methods

Both quantitative and qualitative approaches are used in the research, two approaches strengthen each other (Hussein, 2015). To determine the validity of the concept of science capital, I conducted a survey including 992 students from three kinds of secondary schools: a school in a metropolitan area, a school in a middle-income city and two rural schools. In addition to the survey, I interviewed 23 pupils, parents, and teachers, to investigate their science capital and science engagements in depth. Participants were recruited via my personal connection with head teachers. The questionnaires were collected with assistance of teachers, and semi-structured interviews were constructed online due to the COVID restrictions.

Preliminary Findings

Firstly, the quantitative analysis shows that the index of science capital is valid in predicting Chinese student's science engagement and science-related career aspirations. The more science capital one student has access to, the more likely they are to continue to study science or peruse a science-related job. However, the correlation is much more significant among rural students, which reflects a development gap between rural and urban students. Furthermore, similar to the findings from UK research, Chinese girls have lower aspirations to scientific careers and further science learning. According to the interviews with students, parents and teachers, the reasons may be a combination of gender stereotype, family expectations and their own experience. The social inequality in Chinese secondary science education will be further discussed in next stage.

Additionally, data analysis also show that Chinese students have active science engagement after the outbreak of COVID. 60% of participants follow the updating science news about COVID. 66% of respondents talk about COVID-related science topics frequently with their family members, 59% talk with peers, 56.33% talk with teachers. More importantly, the science capital (scientific literacy, science media consumptions, science communications, etc.) accumulated during the pandemic formulate much higher aspirations to medical or science-related jobs among Chinese students. 76.22% of participants are more willing or strongly more willing to become doctors or science workers than pre-pandemic.

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A Mixed Method Analysis of Perception and Performance under Multiple Active Learning Methods in Undergraduate Biological Courses

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Keywords: Biology, Tertiary Education, Active Learning, Large Group Instruction

Focus of the Study

A major unaddressed challenge is how specifically to design and implement instructional strategies that engender active learning in high enrollment courses. Active learning may include student engagement through discussions, active movement, application, and more (Bernstein, 2018; Cavanagh, *et al.* 2016; Michael, 2006 & Wilke, 2003). My research in active learning is designed to discover student's perceptions to improve learning and retention of material. A second research component in active learning presents student's performance on summative exams under different active learning modalities: kinesthetic and movement, discussion, and problem-based learning, to provide a comparative analysis. Perceptions and performance will be further addressed by comparisons of the same active learning modalities across the discipline of biology in large enrollment undergraduate courses.

Despite repeated calls to involve students in active learning, changes lack widespread implementation in all levels of education (primary, secondary, tertiary) (Michael, 2006; Miller *et al.*, 2013). In part this is due to the variability in active learning theories and evaluation of them (Cattaneo, 2017). Active learning can be defined as involving the student directly in the learning process (Ebert-May *et al.*, 1997) and henceforth shall be defined further as utilizing activities purported to support content understanding and retention.

"The work of Johnson *et al.* (1991) brought the value of active learning, with the research data to support their claims, to the university level, and argued even large classrooms could be crafted as student-centered learning environments." (Machemer & Crawford, 2007) There is a gap in this current literature concerning large enrollment lecture courses that employ active learning routinely and vary the active learning format to aid all students in understanding content (Machemer & Crawford, 2007; Bernstein, 2018; Cleveland *et al.*, 2017). This is especially evident in science courses. Furthermore Cleveland et. al. (2017) notes there is lack of comparison research on the 'effectiveness of various types of active learning'. The goals of this study are to analyze student responses, exam scores and any relationships between the two within and across undergraduate biology courses (Creswell, 2013).

Review of Literature

At the core of constructivist theory is the construction of an individual's own knowledge and the meaning of it. Students must incorporate new information into their own schema and find a way to integrate it or create a new approach. They must do so by interacting with the material either mentally or physically (*et al.*, 2007). Based on constructivist theory, teaching strategies affect student's cognitive and social learning, and active learning spawns this meaning from these experiences in the classroom (Powell & Kalina, 2009; Ertmer & Newby, 2013). Active learning involves the learner in the process of constructing the new knowledge and incorporating it into their own schema (Yilmaz, 2008).

The extant literature remains in need of research on students' perceptions of the continuous use of multiple active learning modalities to aid in understanding science content in a large group setting. In addition, research on student perceptions of active learning is limited and contradictory (Machemer & Crawford, 2007). Studies pulling together student perception data and student performance data have been in great need to offer insight to the outcomes active learning teaching investments can offer (Hyun *et al.*, 2017).

Research Questions

1. What is the relationship between active learning techniques and student performance on summative assessments and how do they compare across semesters of a single undergraduate biology course?
2. What are the student perceptions of the continuous use of different active learning methods on student classroom learning and content comprehension and how do experiences compare for each case across a single biology course?
3. What is the relationship between kinesthetic, discussion, and problem-based active learning methods on student performance on summative assessments and how do they compare across undergraduate biology courses?
4. What are the student perceptions of the continuous use of kinesthetic, discussion, and problem-based learning active learning methods on their classroom learning and content comprehension and how did experiences compare for each course?

Research Design and Methods

Methods of active learning for this study were selected from Bernstein (2018), Michael (2006), and Wilke (2003) after literature review. The three methods utilized include: kinesthetic and movement, discussion, and problem-based learning (Bernstein, 2018). The rationale for including multiple methods of learning is to engage students with the material by varying the method to allow more students to find at least one modality they highly engage with (Breckler & Yu, 2011). Biology courses are selected based on volunteers utilizing active learning instructional methods.

To address research questions 1 and 2 in a single biology course, Human Physiology, a survey via Google Forms and University-wide course evaluation was given at the conclusion of the semesters (Spring 2019, Fall 2019). In an attempt to provide a detailed understanding of student perceptions, a case study approach was used to gather data (Creswell, 2013). Each semester is considered its own case. Confirmatory questions using a Likert Scale (1-5) assess the impact of active learning on students' course knowledge, and perceptions surrounding active learning as it impacts student learning in a large group environment (Teddlie & Tashakkori, 2009). Open response comments were also collected. Quantitative data from student performance on summative assessments was used to discern the relationship between active learning techniques and how they compare across semesters in the Human Physiology course.

Analysis occurred at the end of the semester by coding qualitative data and statistical analysis. After coding, meaning and examples were recorded for each question across individuals and Likert questions categorized based on frequency. Statistical analysis of exam scores included an ANOVA with a Tukey's comparison. A mixed design allows for qualitative data to help support and expand on the quantitative data as a key concept to mixing, concluding in interpretation of both strands together (Plano Clark *et al.*, 2008; Teddlie & Tashakkori, 2009).

I will gather and analyze data (using both coding and MANOVA) from across two more biology courses utlizing the same active learning methods in instruction. Comparisons across biology courses will examine trends in performance and perceptions based on the three active learning methods.

Preliminary Findings

Research questions 1 and 2 were completed during the Spring 2019 (n=436) or Fall 2019 (n=419). Students learned the same content under different active learning methods for the duration of one unit at a time before taking a summative exam per each unit (Table 1).

Table 1. Unit summative exam averages per active learning method.

Method	Semester of 2019	N	Exam Mean	Std. Dev.
Kinesthetic	Fall	436	84.20	
	Spring	419	84.21	
	Overall	855	84.20	12.37
Discussion	Fall	436	82.56	
	Spring	419	80.68	
	Overall	855	81.64	12.27
Problem-Based	Fall	436	83.83	
	Spring	419	82.17	
	Overall	855	83.01	12.38

Students ranked the three forms of active learning in preference of the most knowledge gained. For the Spring of 2019, discussion was preferred (28.5%) over both kinesthetic and problem based learning (27% each). For the Fall of 2019 problem based learning was preferred (28.9%) over discussion (26.4%) and kinesthetic (25.0%). Retention of content was also highest for kinesthetic by a large margin.

Coding responses revealed three themes: large class environment of active learning, the methods of teaching in regards to structure of the curriculum and students response to it, and lastly students content knowledge and understanding improvement. The mixed methods approach allowed me to discover student exam scores did not always align with their perceptions for learning. In addition, positive comments received on the multiple forms of active learning conducted provides evidence that utilizing more than one form of modality in instruction can benefit a wider audience of students.

I will be prepared to discuss in greater detail results from questions 1 and 2 and the preparations for questions 3 and 4 now that most institutions are returning to face to face instruction.

In this international experience I hope to strengthen my methodology in my own research by learning from mentors and peers and to begin networking globally on issues in higher education.

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3.6 Mentor Group 6 | Grachten | 3.6.3

Development of a Learning Environment for Pre-service Teachers for a Systematic Analysis of Curriculum Materials

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Keywords: Physics, Tertiary Education, Curriculum Materials, Curriculum Use

Focus of the Study

The development of curricula and curriculum materials is at the core of science education research. Curricula are in the context of this study learning programs for physics topics, following some guiding principles. In German-speaking tradition of physics didactics, such curricula have been developed since the 1970s. Some of those curricula have been evaluated and shown impressive students' learning outputs, when enacted in school settings (e.g. Burde, 2018; Haagen-Schützenhöfer, 2017). The most important way of communicating research-based curricula are curriculum materials (Breuer, 2021), which are all resources intended to guide teachers' instruction in classroom (Stein *et al.*, 2007). However, these research-based curricular innovations do not find their way in the broad school practice easily (Breuer, 2021), and if they do, teachers often process the provided curriculum materials heuristically and use them only fragmentary (Boesen *et al.*, 2014; Breuer, 2021). In my PhD project I want to address this problem by designing a learning environment for preservice physics teachers within their education at university, where they learn how to analyse curriculum materials systematically.

Theoretical Background

Curriculum materials are very important in guiding teachers practice in classroom (Remillard, 2005), yet the influence of curriculum materials on student learning depends on several factors (Stein *et al.*, 2007): Curriculum materials (*written curriculum)* are firstly read by teachers, who interpret them based on their beliefs and knowledge. Based on this interpretation, teachers adapt or change the materials to the needs of their students or the school context and plan the lessons (*intended curriculum*). Although the *enacted curriculum*, finally taking place in classroom, is based on the planned curriculum, there are changes to be made due to e.g., unexpected student behaviour. Furthermore, with a constructivist view on learning, teachers only can provide learning environments within the enacted curriculum and whether students actually learn or not, depends on several further factors (Schrader & Helmke, 2008). In short, the conclusion is that the influence of curriculum materials on students' learning depends on the students themselves, the context of teaching and – most importantly for the following argumentation – teachers and their interaction with curriculum materials and thus, their construction of the enacted curriculum.

The first step in this process of constructing the enacted curriculum, is to *analyze* the written curriculum. Sherin and Drake (2009) developed a framework to investigate teachers' curriculum use based on empirical findings and differentiated analyzing curriculum materials between three steps: *read*, *evaluate* and *adapt*.

Hence, the ability of teachers to analyze – read, evaluate, and adapt – curriculum materials is fundamental for their teaching practice. This ability needs to be supported in teacher education

(Beyer & Davis, 2009; Schwarz *et al.*, 2008). Drake *et al.* (2014), for example, formulated principles – based on research and their own design work – for designing teacher education courses to support preservice teachers ability to "read and use" educative curriculum materials in a way to develop their knowledge about teaching. The term *educative* indicates here that curriculum materials also aim to promote teachers' learning (Drake *et al.*, 2014). However, most of the available physics curriculum materials in German-speaking regions are not intended to be educative for teachers. A lot of didactical considerations guiding the development of curricula are implicitly hidden in provided curriculum materials.

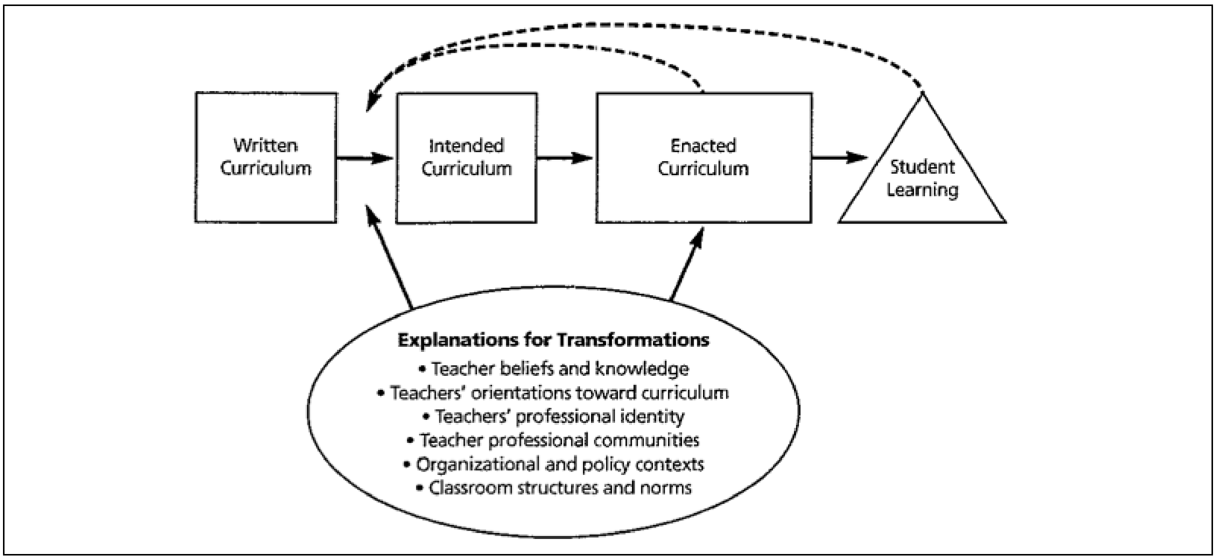

Figure 1. Model for the transformation of curriculum materials into student learning. (Stein *et al.*, 2007).

Thus, to teach based on curriculum materials – and their fundamental ideas – it is important that teachers learn to analyze any curriculum materials, but especially those of research-based curricula, in a way to find those hidden considerations. Therefore, the focus of this PhD project is to help preservice teachers develop their ability to read curriculum materials in a way to identify essential characteristics and their didactical underpinnings, as a first step in their analysis of those curriculum materials.

Research Questions

The objective of the PhD project is the iterative development of a learning environment for preservice secondary physics teachers, where they learn how to *read* curriculum materials systematically. Within this development the following research questions will be addressed:

1. How can preservice physics teachers be supported to read curriculum materials systematically in a way to identify features of the underlying curriculum that are supportive for learning and their didactical underpinnings?
2. How do preservice physics teachers read curriculum materials of a particular curriculum (Frankfurt/Grazer curriculum for introductory optics)?
   a. Which elements or aspects of the provided curriculum materials do they identify as supportive for learning?
   b. How accurately do they identify the essential didactic characteristics of the curriculum and their rationales within the provided curriculum materials?
   c. Which aspects (representations, content structure, …) do preservice physics teachers focus on, when reading the provided curriculum materials?

Research Design and Methods

The development of the learning environment is orientated toward the paradigm of Design-based research (Barab & Squire, 2004). The starting point of a Design-based research (DBR) project is usually a practical problem. An approach to address this problem in educational research is to design, for example, a learning environment, instructional materials, or a digital tool, guided by well-founded design principles, which are derived from empirical evidence or theory. The idea of DBR is then not only to design some kind of solution, but also to study the occurring learning processes in a naturalistic setting and furthermore to generalize findings (Barab & Squire, 2004).

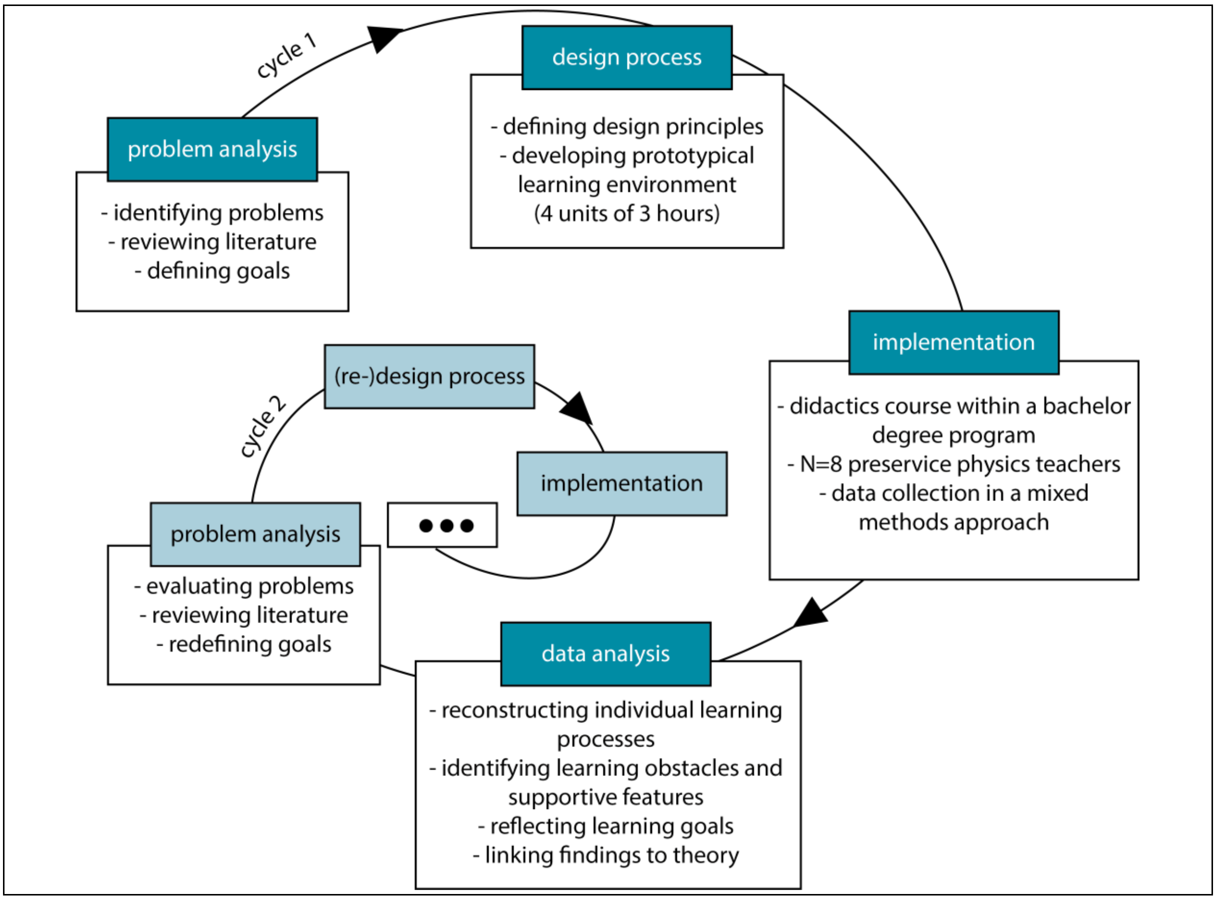

Figure 2. Schematic visualisation of the iterative development of the learning environment with a focus on the first cycle of iteration.

Therefore, in a first cycle of iteration (see Figure 2), based on a detailed analysis of the problem, learning goals were set, design-principles derived and a learning environment (4 units of 3 hours) developed. This prototypical learning environment was implemented in a didactics course within a bachelor's degree program for preservice physics teachers (N=8). During implementation data was collected on several occasions following a mixed-methods approach, using text vignettes (see Skilling & Stylianides, 2020), teaching experiments (see Komorek & Duit, 2004) and learning products, resulting from the teaching experiments (see Figure 3). Additionally, problem-centered interviews (see Witzel & Reiter, 2012) will be conducted after implementation.

In a next step, the collected data will be analysed, and the individual learning processes of the participating preservice teachers will be reconstructed to reveal possible learning obstacles and supportive features of the learning environment, regarding the set goals. Furthermore, the text vignettes – piloted in a preliminary study (N=17) – shall provide deeper insights into the pre-service teachers' processes of reading curriculum materials in a way to identify supportive features of the underlying curriculum and their didactical underpinnings.

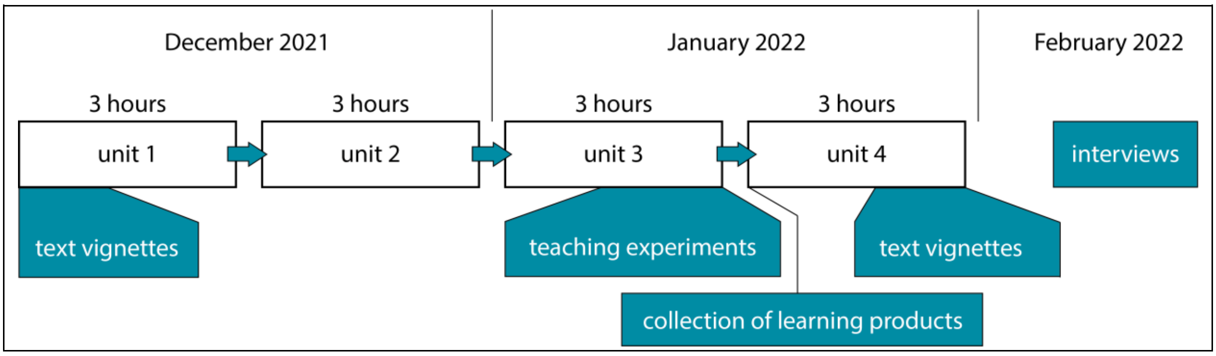

Figure 3. Data collection during and after the implementation of the prototypical learning environment within a course of a preservice physics teacher bachelor degree program. N=8.

The findings of the first cycle of iteration will be linked to existing theory and will be a starting point for further cycles of iteration: An evaluation of the problem, refinement of design-principles, an adaption of the prototypical learning environment, further implementations, and data collections and so on, with the broader objective of contributing to domain specific theories about teaching and learning in mind to sustainably support teacher education.

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3.6 Mentor Group 6 | Grachten | 3.6.4

Investigation of Competencies of Secondary Chemistry School Teachers for Digital Content Deployment and their Mediating Factors

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Keywords: Chemistry, Secondary Education, Digital Competences in Chemistry Education, Usage of Digital Media Elements

Focus of the Study

The integration of digital technologies into educational settings is an important and necessary element in modern education (e.g. OECD 2015). However, a fruitful integration into classrooms depends, among others things, on the digital and professional expertise of teachers. A lesser focused aspect of digitalization in chemistry education is, how to foster this expertise in teacher training as demanded by German schools and the Kultusministerkonferenz (KMK, 2016). This PhD project aims to contribute towards addressing this demand.

The PhD project aims to provide insight into how digital content is being deployed effectively by secondary school chemistry teachers and the aspects mediating the its deployment. Furthermore, to investigate which professional competencies preservice chemistry teachers should acquire we aim to analyse why teachers implement the digital content in their chemistry lessons and if it is effectively implemented. Finally, this project wants to look into how chemistry teachers structure their lesson planning regarding digital content provided by a freshly created learning environment and if fruitful learning paths can be described.

Theoretical Background

Project Basis – A Web-based Learning Environment

This PhD project is embedded in a collaborative project between our institute and a charitable foundation. Goal of the collaborative project is the content creation for a web-based chemistry education learning environment which is as a basis for intended surveys. It was therefore necessary to guide and facilitate the preliminary content creation process.

The design, structure and content of the learning environment were based on the “eChemBook” by Ulrich & Schanze (2015). A guideline for content creation given to the content creators not only had to cover all national curricula but also had to combine cognitive theories (e.g. Sweller, 2011; Mayer, 2014), motivational theories (e.g. Krapp, 1992; Deci & Ryan, 1993) and educational approaches (e.g. Duit & Treagust, 2003; Posner *et al.* 1982; Schanze & Girwidz, 2018).

The learning environment launched in late November 2021 with 200 web-pages, which cover a broad array of early secondary school chemistry content. All content is created under a creative commons license (CC-BY-NC-SA 4.0) that can be freely adapted for our survey purposes.

Review of Literature

The integration of digital technologies can both amplify good teaching practice and enable students to participate in our digital society (OECD, 2015; Fraillon, Ainley, Schulz, Friedman &

Duckworth, 2019). But research has shown that using technologies as an end in itself is not generally effective for supporting a teaching or learning process, it rather depends on how these tools or digital contents are used (e.g. Hillmayer, 2017; OECD, 2015; Stegmann, 2020). With the KMK strategy paper (2016) an initiative that emphasizes on the relevance of the integration of digital technologies in all parts of education was enacted. However, teachers in Germany stated that they are reluctant to use digital technologies frequently (ICILS, 2018). Moreover, they primarily use technologies to a limited extend using them to substitute previous media like textbooks or processes such as presentations (Fraillon *et al.*, 2019; ICILS, 2018). Many teachers are lacking motivation or expertise; hence the integration of new technologies can be a burden for them (Backfisch, Lachner, Stürmer & Scheiter 2021a; 2021b). Therefore, it is crucial to address the mediating factors of teacher's expertise for applying technologies early on. While studies like Backfisch *et al.* (2021a; 2021b) identified motivational beliefs and professional knowledge as crucial factors, Vogelsang *et al.* (2019) showed that these factors are significantly influenced by preservice teachers training at universities. This is highlighting a high potential to foster the later technology integration in teacher training at universities.

A prominent framework to describe the implantation of technology into education is the TPaCK (Koehler, Mishra & Chain, 2013), which has been recently adapted into the DPaCK (Huwer, Irion, Kuntze, Schaal & Tyssen, 2019) to address our digitized society broader demands. Based on the DPaCK the DiKoLAN (2020) provided a competence framework for digitized science education in Germany.

In conclusion literature provides insight into the skills, mediating factors for technology integration and where and when they're ideally addressed. But concrete conception for fostering the competencies for implementation of digital technologies and chemistry subject content are rare (Huwer *et al.*, 2019). We aim to contribute to the *how* by focusing on the aspect how to foster the professional digital competencies of secondary school teachers.

Research Questions

1. Which professional und motivational factors are mediating the chemistry teacher's integration of digital chemistry content into secondary education?
2. How do secondary school teachers effectively implement the digital elements (provided by our learning environment) in their chemistry lessons?
3. Which digital and professional competencies do teachers use to identify relevant digital elements to integrate into their chemistry lessons?
4. How do chemistry teachers use digital content to structure their lesson planning along a fruitful learning path?

Research Design and Methods

The learning environment serves as adaptable content basis for the intended surveys. To address the research questions, it is aimed to create sufficient content to support a whole content subject of secondary chemistry education.

RQ1 will be addressed with questionnaires for motivational and professional knowledge factors, via the learning environment. Additionally, if more data is needed these factors can be directly surveyed while gathering data for RQ2-4. To survey motivational factettes earlier questionnaire-items from e.g., Rigotti, Schyns & Mohr (2008), Bleicher (2004), Lang & Fries (2006) will be adapted for a 4 point Likert scale. A questionnaire for professional knowledge measurement based on the DPaCK will be constructed and expert reviewed before piloting. The data will be evaluated with common statistics programs like SPSS.

RQ2 and RQ3 will be investigated using interviews. The learning environment enables teachers to create their own content compilations, which can be examined by administrators. It's therefore possible to randomly contact or to identify teachers for an interview. Additionally, a call for participation in secondary schools can help to recruit more participants. To qualitatively describe and categorize our data, it's planned to apply a qualitative content analysis (Kuckartz, 2018).

RQ4 will be addressed in a mixed method approach it's possible to collect qualitive and quantitative data through web-based-questionnaire-dairies, the system content compilation function and guided interviews. Therefore, it's necessary to recruit voluntary chemistry teachers, who are willing to implement the digital elements over the course of one learning unit and cooperate with us. The collected data will to create good practice examples to foster the professional digital competencies in university level chemistry teachers' education.

Preliminary Findings

When the ESERA summer school takes place, I will be able to present:

- A guideline for digital learning content creation and also created content examples
- A questionnaire to survey motivational factors and first preliminary findings
- Hopefully first preliminary findings from guided interviews with secondary chemistry teachers on how they effectively implement digital content into their lessons.

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3.6 Mentor Group 6 | Grachten | 3.6.5

Didactic Choices in Education for Sustainable Development and Citizenship – A Study of Teachers' Choices in Upper Secondary Schools

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Keywords: Science Education**,** Education for Sustainable Development, Upper Secondary School, Teachers' Didactic Choices, Scientific Literacy, Action Competence

Focus of the Study

In this study, the didactic choices of science teachers' will be studied within the frames of a Science Studies Course (SSC) in the upper secondary school. The didactic choices of science teachers will be explored when they plan, carry out, and evaluate teaching with the aim of educating responsible citizens, who actively participate in, and develop, professional and social life from a sustainable development perspective. In addition, this research project intends to investigate whether there are differences and similarities in the teaching of SSC between vocational education and training (VET) programs, which leads to a vocational exam, and higher education preparatory (HEP) programs that prepare for further academic studies, and no particular profession within the upper secondary school. The SSC is a compulsory course in both VET and HEP programs, and for many students, this is the only, and last, course with science content that they encounter during upper secondary school. The subject Science Studies is interdisciplinary, with a foundation in biology, physics, earth sciences, and chemistry. The subject deals with health, energy, and sustainable development; areas of knowledge that have emerged where natural sciences meet social sciences. In this research project, the focus will be on the sustainable development part of the SSC and the interdisciplinary challenges teachers face when planning and teaching sustainable development while simultaneously educating for active, democratic citizenship. Educating for active, democratic citizenship places great demands on the teacher's own civic competence and knowledge of democratic processes. Research shows that science teachers perceive they do not have sufficient knowledge in social sciences, or the didactics of Social Science Studies, to reach this goal in their teaching (Sjöström, 2017). Teachers often simplify issues relating to a democratic citizenship and sustainable development in order for the student to understand, and thus jeopardize students' understanding of the complexity in the interrelationships between environmental, economic, and societal perspectives of sustainable development (Sund, 2015). One way of discussing what scientific knowledge and competences a citizen needs to be regarded as an informed and democratically functioning citizen, is to start from the concept scientific literacy. Another way is to discuss knowledge and competences a citizen needs within the subject of sustainable development. Within the concept of Education for Sustainable Development content and competences are discussed aimed to develop by future citizens. Thus, this study intends to investigate the SSC teachers' didactic choices when planning teaching in VET and HEP programs into actively participating citizen for sustainable development in their social and professional lives.

Theoretical Background | Review of Literature

Education for Sustainable Development

The importance of education in the striving for a sustainable development has been emphasized in several UN policy declarations and reports and UN coined the concept of Education for Sustainable development (ESD) (WCED, 1987; World Summit on Sustainable Development, 2002). Within ESD, content of environmental, social-cultural, and economic concerns are key issues, as well as a complex and sensitive relationship between knowledge, politics, ethics, justice, and human rights (Sandell *et al.*, 2005). Additionaly, ESD have an approach in teaching and learning certain competences (Mogensen & Schnack, 2010). ESD focus on competences supporting participatory and active citizenship, such as co-corporation and problem solving, independent thinking, and learning to deal with a reality of change and uncertainty. Sass *et al.* (2020) recently presented "action competences in sustainable development" (ACiSD), defining competences emphasized in ESD. Especially are competences as critical thinking, problem solving and confidence to act mentioned in ACiSD (Sass *et al.*, 2020). To practice and develop competences, the teachers need to consider teaching methods. Teachers teaching methods can depend on selective teaching traditions as fact-based, normative or pluralistic teaching (Sandell *et al.*, 2005, Sund and Gericker, 2021). In the fact-based tradition, ecological issues are the main content. This tradition usually uses teacher-cantered teaching methods. In the normative tradition, environmental issues are addressed in active learning situations where students seek information and work in groups (Sandell *et al.*, 2003; Borg et al, 2012). In a pluralistic tradition, environmental problems are associated with economic and societal issues and conflicting interests. Students are encouraged to evaluate different aspects actively and critically with learning centered teaching methods (Sandell *et al.*, 2003; Borg *et al.*, 2012). EDS advocates a pluralistic teaching tradition.

In this study the didactic what-question focus on ESD-related subject matters and competences, the didactic how-question focus on the methods used in the teaching of ESD and the why-question focus on the teachers starting point and long-term purposes for their EDS as well as how to motivate the students to learn and become actively participating as a citizens for sustainable development in their social and professional lives.

Scientific Literacy

A broad definition of scientific literacy (SL) refers to *what the citizens ought to know about science* (Laugksch, 2000). However, the general conceptualization of SL masks different views and understandings of *what* the public ought to know about science and who *the public* is. There are many definitions of what the public ought to know within science (DeBoer, 2000; Laugksch, 2000). Additionally, dissensions occur about the practical implications of SL in education (Laugksch, 2000).

Roberts (2007) summarizes SL into two visions (named *Vision I* and *Vison II* of SL). These visions provide different strategies of schools' science education, to develop the student in one of the directions of SL visions. *Vision I* lies in the product and processes of science as in nature of science, learning about science, science concepts and scientific concepts (Sjöström & Eilks, 2018). *Vision II* is described as learning of various science contexts which students faces in their everyday life, including matters as environment, natural resources, personal health and making decision in socio-scientific issues (Roberts & Bybee, 2014). *Vision II* was further developed by Sjöström and Eilks (2018) into *Vison III* of SL within sustainable development. *Vision III* of SL focus on competences in line with competences mentioned in EDS, ACiSD (Sjöström & Eilks, 2018; Sass *et al.*, 2020) and in the pluralistic teaching tradition (Sandell *et al.*, 2003; Borg *et al.*, 2012).

This study seeks to investigate what vision of SL teachers' didactic choices prepares the citizens of the future for.

Research Questions

Study I (The didactic what-question)

1. What content and which competences do SSC teachers include in ESD?
2. Do the SSC teachers choose different or similar content and competences/competences when teaching ESD in VET or HEP programs?

Study II (The didactic how-question)

3. What teaching methods do SSC teachers use when teaching for sustainable development and citizenship at the SSC?
4. Do the SSC teachers choose different or similar teaching method when teaching ESD in VET or HEP programs?

Study III (The didactic why-question)

5. How do the SSC teachers motivate the students to learn and actively participate as a citizen for sustainable development in their social and professional lives?
6. Do the SSC teachers motivate students attending VET or HEP programs in similar or different ways when motivating the students to learn and actively participate as a citizen for sustainable development in their social and professional lives?

Research Design and Methods

A mixed method design will be the design of the study. Qualitative data will be gathered through group discussions in the form of focus groups, with semi-structured and open-ended questions. Focus groups is an established method for gathering data of teachers' reflections on their teaching practice (Kvale & Brinkmann, 2009). Focus groups from three upper secondary schools have met four times respectively. Eleven SSC study teachers were included in the focus groups, where five of the teachers taught VET programs and teachers taught at HEP programs. Transcriptions of audio-recordings from the focus-group meetings will be analysed with content analysis (Mayring, 2000). The results from the analysis will be used to design a questionnaire. The questionnaire will be sent to a large and randomly selected cohort of SSC teachers at Swedish upper secondary schools. Quantitative data from the questionnaire will be statistic analysed with the aim to answer the research questions.

Preliminary Findings

Preliminary data from the first focus group meetings have been transcribed, and the didactic what-question has been analysed with content analysis. Four themes of content were found in the ESD of SSC were identified: Energy, Ecology, Biodiversity, and Climate change. Within the four themes the teachers taught about the scientific background of the theme and the impact of the humans' lifestyle. The results showed that the main teaching content that the teachers chose can be placed within the environmental perspective of sustainable development. However, some of the teachers also included some economic and societal perspectives in their teaching, as the importance of education, the correlation between education and human population growth and the need of reducing poverty. But the teachers did not give examples of how these sustainability goal should be reached.

An unexpected finding was that the SSC teachers expressed that it was not their concern to teach about the economic perspectives of sustainability. Additionally, the SSC teachers felt insecure to teach about economic sustainability. The SSC teachers did not express that teaching about the societal perspective of sustainable development was an issue, but still they mostly included an environmental perspective in their teaching.

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3.6 Mentor Group 6 | Grachten | 3.6.6

Mathematical Modelling in Physics and Mathematics Education: Theory and Practice

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Keywords: Physics, Mathematics, Secondary Education, Mathematical Modelling

Focus of the Study

Redish and Kuo (2015) argue that physicists do not merely use math, but rather make meaning with it in a different way than mathematicians do. Physics educators report on mixed success in teaching students how to employ math effectively in physics in this sense (Karam, 2014; Redish & Kuo, 2015; Uhden *et al.*, 2012). Teaching students how to construct mathematical models of physical phenomena and use these models to investigate and make sense of the physical world is a central goal of physics education (Hestenes, 1987; Karam, 2014; Redish, 2006). Mathematical modelling (MM) is also acknowledged as a fundamental practice in science education standards (AAPT, 2014; National Research Council, 2012). However, scholars have argued for more than three decades that traditional physics instruction does not place enough emphasis on modelling and its critical elements (Hestenes, 1987; Lehrer & Schauble, 2010; Redish & Kuo, 2015). The question of how to meaningfully – as opposed to technically – incorporate modelling into the instruction of physics, is still being debated (Redish & Kuo, 2015).

In my home country MM is not included in the K-12 mathematics curriculum. Lately, low achievements in international tests on mathematics literacy (PISA) drew attention to the place of MM in mathematics education (Med). Additionally, research shows that modelling competence is difficult not only for students, but for teachers as well, and there is evidence that many mathematics teachers do not know how to implement it (Maaß, 2006; Shahbari & Tabach, 2020; Vorhölter *et al.*, 2019). Researchers report that although MM *is* present in national curricular recommendations, the methods by which it can be taught have lagged behind, and as a result, MM is not prevalent in school practice (Maaß, 2006; Schmidt, 2010; Vorhölter *et al.*, 2019).

Theoretical Background

MM is 'a process in which mathematics is used to elaborate a realistic problem' (Stillman, 2016, p. 8). The nature of MM is described somewhat differently in the literature of physics education (PEd) compared to its descriptions in the literature of MEd.

Mathematical Modelling in Physics Education

Explaining a physical phenomenon by a physical mechanism often requires representing it by mathematical formulations. Models mediate between theories and the real world. Thus, mathematical models are a basic tool for the acquisition of knowledge of the natural world. Additionally, deductive reasoning represents a crucial aspect of the mathematization of physics – models often precede the theory and contribute to its elaboration (Develaki, 2020; Hestenes, 1987; Lehrer & Schauble, 2010).

Many physics students struggle as they try to develop mathematical fluency. Students often need to blend physical, mathematical, and computational reasoning for constructing a result (Bing & Redish, 2009). To do that they should recognize the structural role of mathematics in physical thought and consciously apply sophisticated strategies to problem solving (Karam, 2014). It seems that experts have an interconnected knowledge structure with complex schemata, which enables them to solve problems better and much faster (Uhden *et al.*, 2012). Sherin defined knowledge elements which he termed 'symbolic forms'. Each symbolic form associates a simple conceptual schema with a pattern of symbols in an equation (Sherin, 2001).

Mathematical Modelling in Mathematics Education

In MEd literature, MM is described as the process of building a mathematical model for solving real-world problems (Kaiser & Sriraman, 2006; Li, 2013), and is theoretically referred to as 'The Modelling Cycle'. The literature in mathematics education suggests different conceptualizations for this cycle (Ferri, 2006).

Kaiser and Sriraman discuss perspectives on modelling in MEd. The central goal of the epistemological perspective is to promote the development of a mathematical theory as an integrated part of the MM process. According to this perspective, model construction leads to the development of a mathematical theory (Kaiser & Sriraman, 2006).

Research Questions

This work aims to examine and compare the conceptualizations of MM and the related instructional practices in physics and mathematics education at the advanced high school levels. This raises the following research questions:

1. What are the conceptualizations of MM in the literature of mathematics education compared to the literature of physics education? What are the differences and similarities between these two bodies of literature?
2. What are the main features of physics and mathematics teachers' didactic considerations and preferences regarding MM? What are the differences and similarities between these teachers in this respect?
   a. What are the educational goals for integrating MM into the instruction of physics and into the instruction of mathematics as perceived by these teachers?
   b. What are the MM related activities, assignments, problems and practices employed in physics classes and in mathematics classes?
   c. What are the formal and informal definitions and representations of central mathematical terms used in both disciplines?
   d. What are the examples and analogies employed in the context of MM in both disciplines?
   e. How are the epistemological aspects of MM treated in the instruction of each discipline?
3. What are the gaps between educational theory (i.e., literature and policy) and the teachers' perceived instructional practice in each discipline?

Research Design and Methods

To answer the first research question, a meta-analysis (Kitchenham, 2004) of the literature on the incorporation of MM in physics has been conducted (see Preliminary Findings section). This meta-analysis will be compared to a similar meta-analysis in MEd that will follow. The procedure of the meta-analysis is:

a. Papers that include the term MM are searched in leading peer-reviewed journals that publish work on PEd / MEd, starting in the year 2000.

b. Articles in which this term is not discussed in the context of science or physics / mathematics are excluded (e.g., mathematical models of cognition, learning etc.).

c. The articles go through two phases of content analysis (Krippendorff, 2018). The purpose of the analysis is to identify the educational goals regarding MM, as well as the articulated activities related to MM. *First phase*: Segments in each article that either reflect goals or activities are highlighted. Twenty percent of the segments are coded as activity or goal by at least one additional member of the research group, and interrater agreement is documented. *Second phase*: categories that describe specific goals and activities are iteratively refined. Twenty percent of the segments that reflect goals, and twenty percent of the segments that reflect activities, are coded by at least one additional member of the research group, and interrater agreement is documented.

d. The frequencies of particular goals and activities are documented, and the associations between goals and activities are examined by Pearson's chi-square test. Principal Component Analysis is conducted on the emerging activities to aggregate activities into thematic clusters.

Preliminary Findings

Following is the abstract of a paper that has been accepted to the NARST 2022 conference.

MM is acknowledged as a fundamental practice in science education standards. Teaching students how to construct and use mathematical models is a central goal of PEd. However, there are ongoing debates on how best to incorporate modelling into physics instruction, and modelling is considered one of the most challenging processes for physics students. This paper reviews conceptualizations of MM in the science and PEd literature.

This review covers 54 articles published in 11 leading peer-reviewed journals since 2000, that discuss MM either as the focus of the investigation or as an illustrative example, component or outcome of the investigation. A content analysis was employed to identify educational goals and activities related to MM as conceptualized in the articles. The frequencies of goals and activities were documented, the associations between goals and activities were calculated, and Principal Component Analysis was applied to aggregate the activities into meaningful clusters.

The analysis suggests that the use of MM in the instruction of physics is more highly influenced by educational approaches that focus on the learning *of* science than educational approaches that focus on learning *to do* science.

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3.6 Mentor Group 6 | Grachten | 3.6.7

How to Foster Student Engagement in Science? Investigating the Effects of Motivational Interventions in a Student Lab

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Keywords: Chemistry, Out-of-School Education, Situated Expectancy-Value Theory (SEVT), Context-based Learning

Focus of the Study

Chemistry is hard to understand, boring, and contributes to environmental pollution and climate change. Such statements mirror some common attitudes of students towards chemistry (Freire *et al.*, 2019) and are consistent with the unpopularity of STEM-related subjects amongst students (Eilks & Hofstein, 2015) – which is an obstacle for the acquisition of scientific literacy or the desire to recruit young talents for STEM professions.

Several approaches designed to support science teachers facing those challenges are located within out-of-school-education, including student labs (NRC, 2015). Latter allocate optimal requirements for educational research since the learning environment can be constructed and controlled depending on the research focus. In this project, the effects of motivational interventions are investigated based on a student lab. Elements of learning environments derived from the theoretical framework of situated expectancy-value theory of motivation (SEVT) by Eccles *et al.* (2020) such as scaffolds or contexts are varied in a systematic way. An evolving field of research within this framework targets interventions to enhance student motivation via manipulation of the subjective task value induced by the learning material or setting, focusing on one of its four underlying constructs – utility value, attainment value, intrinsic value, and cost (Rosenzweig *et al.*, 2021). While the effects of utility value interventions are well-researched, investigations on effects of cost reduction interventions however are rare. This also applies to research on intrinsic value interventions (Rosenzweig *et al.*, 2021). The idea emerged to combine this research gap with an attempt to address students' attitudes toward chemistry through motivational interventions in a student lab. Therefore, the main goal of the present research project is the design and evaluation of an emotional cost reduction intervention as well as an intrinsic value intervention to enhance students’ motivation, ensuing to improve performance in and attitude towards chemistry and science.

Theoretical Framework

By adding an S to the established acronym EVT, Eccles *et al.* (2020) updated the expectancy-value-theory, making it more dependable on the specific situation the student with his or her motivational factors is embedded in (situated EVT). The effectiveness of interventions is therefore situation-specific (Eccles & Wigfield, 2020). The framework characterises motivation as a product of expectancies and values, influencing achievement-related choices and performance through task engagement, having high predictive power for academic outcomes (Rosenzweig *et al.*, 2021).

By defining interest as a part of intrinsic motivation and dividing it into individual interest (as a stable trait characteristic of a person) and situational interest (as a various state depending on time and situation) (Krapp, 1992), the effects of changes in expectancies or values can be measured likewise. Value, or more precisely subjective task value, which describes the perceived importance of a task, is described by four main person characteristics, which are accessible targets for motivational interventions. The explanations of the value components along with some common intervention approaches or suggestions are summarised in Table 1.

Table 1. Overview of explanations and intervention approaches subject to Rosenzweig *et al.* (2021), Eccles & Wigfield (2020), Linnenbrink-Garcia *et al.* (2018), and Flake *et al.* (2015)

	Explanation	**Intervention Approaches**
Utility Value	Usefulness of task	Reading or writing prompts about usefulness of course materials for self/others
Attainment Value	Importance of doing well in task	Self-reflections helping students to investigate what is important for their identity/future self in form of writing prompts or quotation reading
Intrinsic Value	Anticipated enjoyment of task	Suggestions: Provision of choice (autonomy-supportive instructions), real-world challenging tasks (context, relevance-supportive instructions), active engagement (hands-on activities), communicating content in an enthusiastic way, give general support or support of belonging, make material more stimulating
Perceived Cost	Negative appraisals of investments/sacrifices for a task	Reinterpreting costs as less negative or worthwhile by means of quotes/advice from older students (reading and ranking, presentation, video)

Intrinsic value described as the anticipated enjoyment one expects to gain from doing a task is related to intrinsic motivation (Rosenzweig *et al.*, 2021). It can be influenced by fulfilling the basic psychological needs (autonomy, competence, relatedness) as the self-determination theory by Deci and Ryan (2000) proposes. According to a meta-analysis by Rosenzweig *et al.* (2021) there are indeed no specific intervention designs targeting intrinsic value, but suggestions are made, which are collected in table 1. It should be added, that contributions to this objective are known from fields of science education research like context-based learning, having the potential to increase interest towards the course content, resulting in a more positive attitude towards the subject (Habig *et al.*, 2018). However, these approaches have rarely been considered from an EVT perspective.

Since the provision of choice is coherent with the self-determination theory and suggested by several authors (Rosenzweig *et al.*, 2021; Lazowski & Hullemann, 2015; Linnenbrink-Garcia *et al.*, 2018), this intervention suggestion is chosen to be the basis of the intrinsic value intervention design of the present project.

Perceived costs differ from the residual value options as they reduce the extent to which someone values a task and can lead to avoidance behaviour (Rosenzweig *et al.*, 2019).

There are suggestions to distinguish between categories of cost types (as shown in Table 2), such as those described by Flake *et al.* (2015).

The emotional cost defined as the perceptions of negative emotional consequences of pursuing a task (Flake *et al.*, 2015) can decrease interest and is therefore a chosen intervention target in the present project.

Table 2. Explanations of the suggested categories of perceived cost (Flake *et al.*, 2015)

Task effort cost	Negative appraisals of time/effort/amount of work while engaging in a task
Outside effort cost	Negative appraisals of time/effort/amount of work while engaging in a task instead of a task of interest
Loss of valued alternatives cost	Negative appraisals of what is given up when engaging in a task of interest
Emotional cost	Negative appraisals of a psychological state while engaging in a task

Research Questions

The combination of research gaps within the SEVT framework, societal goals according STEM education, as well as the opportunity of designing a student lab environment yields the following research questions for the project:

1. To what extent does an emotional cost reduction intervention (through provision of insights in the forthcoming student lab visit as part of course preparation) affect students' learning motivation, performance and attitudes towards STEM?
2. To what extent does an intrinsic value intervention (through provision of choice of the contextual framing for the program of a student lab visit) affect students' learning motivation, performance and attitudes towards STEM?
3. In what ways do both interventions influence the development of students' situational interest during the student lab?

Research Design and Methods

Due to the presented theoretical deliberations the project can be intersected in two main studies focusing on the chosen intervention designs using a mixed methods approach. Both studies are characterised as experimental pre-post-design intervention studies and placed within the same student lab program. In a period of two days the students of grade 8/9 are divided into teams of two and supplied with an iPad, which uses an application with three functions:

- It guides the students through the different tasks and lab experiments they must accomplish, using a learning companion embodied by an avatar (ocean researcher) serving as a scaffolding tool.
- In addition, the application is used as a documentation journal for the hands-on activities.
- Thirdly, standardised questionnaires are planned to be incorporated into the app.

The selected lab experiments address different influence factors of carbon dioxide concentration in atmosphere and ocean, framed by the topic of ocean acidification. The questionnaires are supplemented by real time measurement of the situational interest (feeling-related and value-related valence) and semi-structured interviews right after accomplishment of an experiment on randomly chosen student teams. The planned categories of survey data are summarized in Table 3.

The *emotional cost reduction intervention* takes place at the schools of the participants within the frame of course preparation of the forthcoming lab visit. The classes are randomly assigned to the intervention conditions. For the experimental condition a video presentation is given, supplying the students with information about the lab equipment, planned agenda and some insights into the planned activities the students must accomplish. Within the control condition the students receive a video with no relations to the planned visitation.

The planned intervention tends the uncertainty of students being faced with foreign environments by preparing them emotionally and cognitively for the lab visit.

This *intrinsic value intervention design* does not require the visit of the participants in their classroom. Within the experimental condition the students are prompted to choose the context (ocean acidification, blood acidosis, or gas accumulation in beverages) of the lab program via iPad. The storyline of the chosen context connects the experiments of the program, implemented by guidance from a learning companion. The content as well as the conducted experiments do not differ between the three context framing options. The randomly assigned control group does not get the provision of choice and must work with the ocean acidification context. The context framing themes were chosen based on the findings of the ROSE-study (Sjøberg & Schreiner, 2010). The aim is to spark interest and help the students enjoy the activity they are conducting.

Table 3. Overview of the calculated survey data.

Dependent Variables	Situational interest (feeling-related and value-related valence), content knowledge
Independent Variables	Emotional Cost Reduction Intervention, Intrinsic Value Intervention
Control Variables	Pre-knowledge (common chemistry topics and student-lab-related topics), demographic data (especially gender and socioeconomic background), last grade in chemistry, interest in chemistry as a subject, chemistry self-concept
Topics of the interviews	Expectations towards the student lab visit, leisure-time interests, attitude towards chemistry and chemistry education, justification of the context choice, problems within the lab program, frequency of hand-on activities in class, professional ambitions

Quantitative data analysis will include correlation and regression models, as well as latent state trait modelling to examine the development of situational interest. The interview data, on the other hand, will be categorized and evaluated using qualitative content analysis for each intervention study.

Preliminary Findings

Current situation of the research project is within the planning and design stage, scheduling first class visits in the student lab for June 2022. Hence, first results can be reported by the start of ESERA summer school 2022, setting a foundation for discussion of the project, which I would highly appreciate.

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3.7 Mentor Group 7 | Duinen | 3.7.1

Promoting Pre-service Teachers' TPACK in the Physics Classroom – A Development and Evaluation Study

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Keywords: Physics, Teacher Education, Digital Media

Focus of the Study

Research in physics education has shown that many students do not succeed in developing an adequate understanding of basic physical concepts. Preconceptions play a central role in developing physical concepts as they have a significant influence on the processing of new information (Schecker *et al.*, 2018).

One way to facilitate students' conceptual understanding is through the use of digital media, as they have the potential to enable a new quality of visualisation (Girwidz, 2020). However, very few teachers have learned in their teacher training how to use digital media effectively in the classroom (Eickelmann *et al.*, 2019).

Against this background, it is important that pre-service teachers are qualified to be able to use digital media in a way that is appropriate for students and foster students' learning (Vogelsang *et al.*, 2019). To this end, we develop and evaluate a seminar as part of a joint project at three universities, in which pre-service teachers not only learn about the educational potential of digital media in physics lessons, but also plan, implement and reflect on their use in practical phases.

Theoretical Background

A framework model for professional competence and skills of prospective physics teachers was developed by Riese (2009) based on Baumert and Kunter (2006) with the dimensions professional knowledge, beliefs or values, motivational orientations and self-regulatory skills. According to this model, the professional knowledge of teachers is subdivided into the three areas of content or physical knowledge (CK), pedagogical knowledge (PK) and physics related pedagogical content knowledge (PCK). Based on prior work of Gramzow *et al.* (2013), it is assumed that PCK is subdivided into eight facets whereby, in addition to the facet "dealing with preconceptions", the facet "(digital) media" is of particular interest for our study.

The motivational orientation as part of teachers' professional competence was modelled by Vogelsang *et al.* (2019) with explicit reference to the use of digital media in science teaching on the Theory of Planned Behaviour (Fishbein and Ajzen, 2011). In addition to professional knowledge and motivational orientations, the self-regulation of pre-service teachers is considered a competence facet in this model.

Another variable of the area of beliefs that has been shown to influence the quality of the use of digital media is the utility value (perceived usefulness) of teachers towards digital media (Backfisch *et al.* 2020).

According to the model of professional competence according to Blömeke *et al.* (2015), (facets of) professional competence should affect observable teacher action ("performance"). Tondeur *et al.* (2012) provided a cross-disciplinary approach to supporting student teachers in integrating digital media meaningfully into their teaching with their synthesis of qualitative evidence (SQD) model. According to the model, it is central in seminars, among other things, that pre-service teachers receive feedback so that they have the opportunity to reflect, collaborate and that they have authentic experiences with digital media.

Research Questions

The primary objective of the present study is the development and evaluation of a research-based and effective seminar that aims to promote conceptual understanding with digital media in the physics classroom.

A Development

A.1 What previous experience and interests in relation to individual digital media do pre-service teachers have?

A.2 Which aspects of the seminar do pre-service teachers feel contribute significantly to the quality of the seminar?

B Evaluation

B.1 How does the professional competence (based on Riese, 2009) of pre-service physics teachers develop during the seminar with regard to ...
   a. the facets "digital media" and "preconceptions" of PCK?
   b. motivational orientation?
   c. self-regulatory skills.

B.2 To what extent are pre-service teachers able to plan high-quality teaching using digital media and to implement it in exemplary teaching sequences?

C Insights for the Theory

C.1 Which learning prerequisites (e. g., motivational orientations, PCK) favour the development of the "digital media" facet of PCK?

C.2 How could a seminar for promoting pre-service teachers' professional competence in digital media in physics teaching be designed?

Research Design and Methods

The seminar conception and evaluation follows the Design-Based Research approach (DBR; Collins *et al.*, 2004), whereby the seminar is systematically developed and evaluated in iterative cycles of design, evaluation and re-design (see Figure 1). Following the DBR approach, the seminar concept is based on a theory- and research-led procedure, which means that in addition to a literature review, we also carried out a needs analysis with study participants.

The further development of the content of the seminar is based on a triangulation of quantitative and qualitative data. It is supplemented by a particular focus on the question of the extent to which the seminar can contribute to an increase of the professional competence of teachers.

In a pre-mid-posttest design, PCK, motivational orientations, and self-regulatory skills are surveyed with quantitative items during the implementation of the seminar. In this way, the developmental processes in the investigated areas of professional competence are traced. The test by Riese, Gramzow and Reinhold (2017) from the ProfileP-Transfer project is used for the survey of PCK for the facet "preconceptions", whereby the originally open answers were converted into a closed format. For the facet "digital media", a newly developed test was used (Große-Heilmann *et al.*, 2021).

The area of motivational orientations includes the scales Motivation for Use, Expected Difficulties, Social Norm and Attitude towards the Use of Digital Media, using the items from

Vogelsang *et al.* (2019). In addition, the self-efficacy expectation, as already used in the needs analysis, and the utility value are surveyed following van Braak *et al.* (2004).

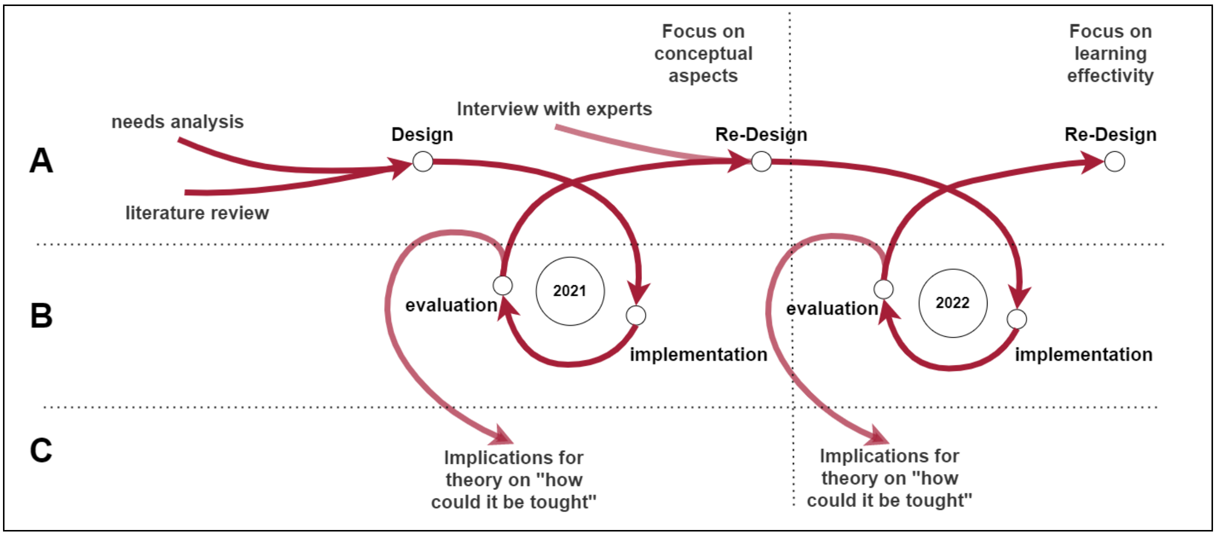

Figure 1. Further development according to the DBR approach.

In order to assess the self-regulatory ability to evaluate one's own performance, an assessment of one's own performance is requested for the above-mentioned tests on the two facets of PCK before and after taking the tests.

Further, the pre-service teachers' perceived quality of the seminar is quantitatively assessed in the post-test using 5-point Likert scales using an evaluated test, based on the SQD model (Tondeur *et al.*, 2018). In addition, the individual seminar sessions are also evaluated. Here, the pre-service teachers assess the processes of the individual seminar sessions by filling out so-called one-minute papers (i.e., self-declarations by the pre-service teachers on the content learned in the respective seminar sessions) after each session. In addition to the opportunity to reflect on what they have learned, open questions and their assessment of the course of the session are also collected. The answers can help to sharpen the individual seminar sessions.

Pre-service teachers' competence to plan quality teaching with digital media is to be carried out through a qualitative analysis of the teaching sketches and video-graphic teaching sequences, which were conducted in the seminar. To identify particularly successful and suitable learning opportunities as well as problem areas, final interviews will be conducted with the pre-service teachers after the end of the seminar. This will give the researcher the opportunity to ask for feedback, the perceived quality of the seminar, and the learning materials. In addition, an expert survey will be conducted in order to further improve the seminar.

The evaluation follows a mixed-methods approach. The development of professional competence over the course of the seminar is analysed using comparisons of mean values (probably ANOVA and t-test). In addition, qualitative data will be analysed using a qualitative content analysis method.

Preliminary Findings

As part of the needs analysis on the topic of digital media in physics teaching, the pre-service teachers' interest in individual physics-specific digital media was surveyed in addition to their previous experiences. A total of $N = 77$ pre-service physics teachers (female = 46, male = 30, diverse = 1) from six universities took part in the needs analysis conducted online.

Preliminary results indicate that pre-service teachers' prior experience with digital media is very heterogeneous and differs significantly between different digital media ($\chi^2(10) = 231.03$, $p < 0.001$ by Friedmann test). In addition, an analysis of variance (ANOVA) showed no significant differences in location ($F(1, 814) = 3.77$, $p = 0.053$). The partly low level of previous experience contrasts with a generally high level of interest in the use of different digital media in physics lessons.

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3.7 Mentor Group 7 | Duinen | 3.7.2

Scaffolding Argumentation in University Level Science Education

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Keywords: Physics, Tertiary Education, Scientific Argumentation, Physics Argumentation

Focus of the Study

Learning argumentation and argumentation skills is an integral goal of science education (Rapanta, Garcia-Mila & Gilabert, 2013). Learning argumentation and its skills can serve students in two ways: first, learning argumentation is connected to better learning outcomes and understanding of content knowledge (Rapanta, Garcia-Mila & Gilabert, 2013), and second, argumentation is a generic skill and with proper content knowledge, it enables students' successful participation in discussions on i.e., socio-scientific issues, and make informed decisions (cf. Jiménez-Aleixandre & Erduran, 2007).

Even though the importance of argumentation as part of science education is well-known issue within science education in schools, less attention has been paid on domain-specific argumentation and argumentation skills at university level science education, nor is there a mutual understanding how it should be addressed (cf. Engelmann, Chinn, Osborne & Fisher, 2018). As a domain-general skill, argumentation is agreed as useful generic skill. However, research has shown that such generic skills do not develop automatically in higher education and they need to be practiced in particular (cf. Fischer *et al.*, 2014). Poor generic skills might hinder student's deeper understanding of scientific knowledge and progressing in studies and even in performing in working life.

Research on learning scientific argumentation mostly concentrates on learning the argumentation process and rational argumentation (for review, see Osborne, Erduran & Simon, 2004) instead of learning argumentation which proceeds from empirical evidence and pays attention to formation and evaluation of justified claims based on evidence. The latter approach we call evidence-based argumentation. For the goals of learning physics in higher education, using evidence in building explanations is central. In learning scientific ideas and theories, university students need to build their understanding on investigation of data and elaborating arguments. To evaluate evidence, students need to understand the criteria for science and based on evidence-based scientific arguments one can decide which proposed explanation is correct (Brigandt, 2016). This study focuses on physics-specific argumentation and students' argumentation skills in university level.

Theoretical Background

Studies on learning argumentation form a broad field. Researchers use many argumentation models that stem from different objectives and thus are inconsistent with each other. Therefore, depending on the objectives, understanding of argumentation's goals, structure and evaluation differ (Rapanta *et al.*, 2013; Wohlrapp, 2014). Most argumentation models base on Toulmin's argument pattern, TAP (1957/2003), which in turn is based on analyzing argumentation in court hearings and focuses on argument structure. It is widely used also in science education even though it obviously does not consider how scientific knowledge is built and what counts as credible scientific justification. The importance of paying attention on epistemic theories influencing argumentation has been noted both more broadly (Wohlrapp, 2014) and specifically in science education (Sandoval & Millwood, 2007).

There are several models to analyze argumentation or arguments, but they tend to be very general and we long for precise enough criteria to analyze evidence-based argumentation in the context of physics. The idea is somewhat present in many argumentation models in science education. In some models, the use of empirical evidence is analyzed quite thoughtfully from what evidence is used and how its meaning is explained to recognizing the need of criteria to what counts as sufficient and relevant evidence (cf. Sampson *et al.*, 2011). Still, this model does not explicate how we identify relevant and what is sufficient. In addition, models that emphasize the use of evidence tend to ignore the use of theory, which is an essential part of knowledge building in physics.

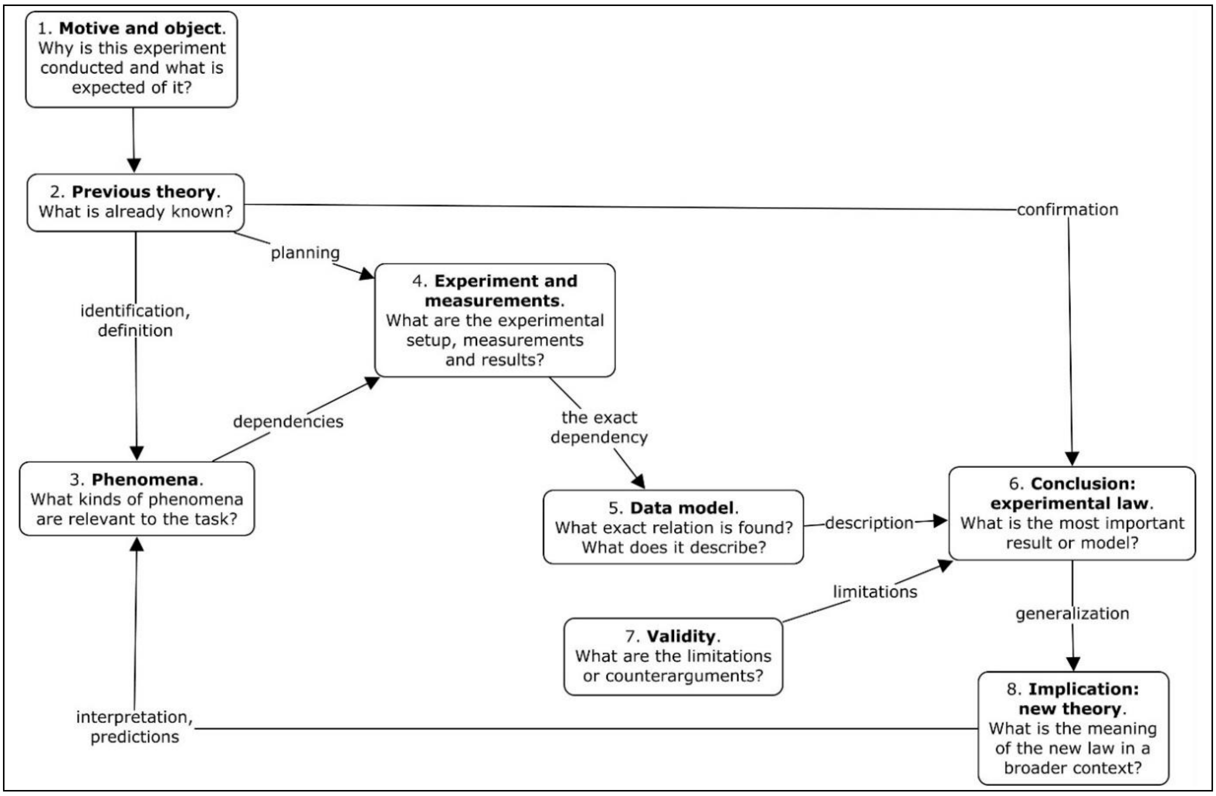

Figure 1. Argumentative moves for an experimental law of physics and their relations (applicant, 2020; see also Nousiainen, 2017).

One possible solution to analyze or scaffold students' argumentation and knowledge organization, is to apply physics-specific knowledge justification scheme (KJS, see Figure 1), which explicates central argumentative moves and their relations for a law of physics (Nousiainen, 2017). The idea reminds of TAP (1957/2003) but its contents base on physics. In this study, we review the KJS for experimental physics law, since we are interested in how pre-service teachers build their understanding on both theory and empirical evidence. KJS shows also that argumentation is not just a fact list one needs to give to argue well – it is important to show how different argumentative moves connect to form a sound justification.

Research Questions

We are interested in students' argumentation and specifically how they use empirical evidence and theory when they have been asked to explicitly express their reasoning and are scaffolded in it. The research questions are:

1. What relevant features of physics argumentation are found in students' explanations?
2. How do students explain the meaning and role of empirical evidence or theory in their argumentation?

Research Design and Methods

We carry out a small-scale interpretative study. The research material is in form of written student reports (N=30) and is ready to be analyzed. We intend to do an in-depth interpretative content analysis.

The reports have been collected from a physics teacher preparation course that focuses on organizing physics knowledge in a way that is useful for teaching purposes. Our sample consists of written course assignments where students describe the experiment on photoelectric effect. To introduce the subject and scaffold students in argumentation, students have first read a research article on the phenomenon, analyzed its argumentation and presented it in their own words in the form of KJS. After this, students have given a written explanation of how the phenomenon could be presented in teaching. This is called a didactical scheme (DS, cf. Mäntylä & Nousiainen, 2014; Nousiainen, 2017).

RQ1 is studied by comparing students' reports to KJS. We are interested to see if students use same kinds of argumentative moves and specifically if they use relevant empirical evidence or theory in their explanations. RQ2 is focused on how students use evidence or theory in their argumentation in the sense of how deeply it is connected to the rest of the explanation. From this point of view, weakest argumentation would not use relevant evidence or theory at all or present them unconnected to the rest of the explanation – successful argumentation would present relevant evidence and theory, tell why they are important and show how they lead to the conclusions.

Preliminary Findings

The whole data is already collected and we are familiar with it since we have previously analyzed it from a different point of view (Author, manuscript under preparation). Because the argumentation analysis of this data has not been carried out, we can only speculate of the possible outcomes. Preliminary impression is that pre-service teachers have difficulties in arguing well their explanations even if the argumentation task is scaffolded as described here. Preliminary results indicate the need to enhance pre-service teachers' physics knowledge and their skills to explicate scientific argumentation. The proposed framework reveals significant variation between such abilities.

It remains unclear whether the results tell more about mastering physics knowledge itself or perceiving its necessity in argumentation (Author, 2020). The participants have studied photoelectric effect in their earlier university studies and have been allowed and encouraged to use source material as a base for their explanations. Still, many of them have fundamental problems giving adequate explanations. They may root in students' insufficient understanding of physics content knowledge during earlier basic studies in university (Mäntylä & Nousiainen, 2014).

Even though physics teachers are a relatively small group compared to all scientists or students studying science, they play a key role: physics teachers' argumentation skills influence their own teaching in the future and that way also next generations and their argumentation skills and understanding science. Subject teacher education aims to coherent and well-ordered subject matter knowledge and argumentation and explanation are ways to communicate it in teaching (Fischer *et al.*, 2014; Nousiainen, 2017; Rapanta *et al.*, 2013). Presenting knowledge in logical order and quality of well-argued explanations are both essential parts of well-planned teaching. Still, many in-service and pre-service teachers have insufficient argumentation skills (Author, 2020). There is a need for practical tools to help future teachers organize and consider their own knowledge. These tools could be valuable for other university students and their teachers, as a scaffolding to learn scientific argumentation and physics knowledge better.

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Which way do we steer? Black Students' Access to STEM Undergraduate Studies through Transitional Education Programs

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Keywords: STEM Education, Science Education, Access to Post-secondary, Undergraduate Education, Transitional Education, Bridging Education, Academic Upgrading, Historically Excluded Students

Focus of the Study

Transitional education programs (TEP) serve as access to higher education programs. This study examines how TEPs influence post-secondary enrolment by Black students in Science, Technology, Engineering and Mathematics (STEM) programs in Canada.

Cedillo (2018) argues that STEM education research concerning racial equity needs to articulate anti-blackness, however current research does not use this language in addressing access to STEM. Furthermore, there is little research on TEPs and factors impacting Black student enrolment in STEM.

This study will contribute to the theoretical and practical underpinnings of access to STEM through transitional education for Black students. This study can also have wider implications for access education and marginalized students' enrolment in post-secondary STEM.

Review of Literature

In this section, I discuss the conceptual foundations of this study through an analysis and synthesis of literature on the experiences of Black students in education; STEM undergraduate studies; and transitional education programs.

Experiences of Black Students in STEM

The education system in Canada is a relic of colonization (Knight, 2019). STEM is of particular interest in this case since this field is known to have sources of inequities including curriculum relevance, teachers' knowledge, skills, and beliefs (Carlone *et al.*, 2011). It is also a field with burgeoning career trajectories and in this context, we oppress, deny, and perpetuate systemic inequities. For Black students in Canada there is an ongoing struggle for equity in education even as we continue to build anti-racist practices (Dei, 1996a; Dei, 1996b).

When examining the experiences of Black students and STEM, Cedillo (2018) articulates that "neoliberal standardization combined with racialized student surveillance practices" (p 247) must be examined further to understand how anti-Blackness manifests in STEM education for Black students. To do this, we must also heed that "it is impossible to talk about any possibility of STEM in the current moment and for the long haul without an explicit acknowledgment of the totalizing power of white supremacy" (McGee, 2021, p 8).

While there is research on access to STEM undergraduate studies in the US context, there is a lack of research on this in a Canadian context (DeCoito, 2016).

STEM Education

Science educators are conditioned in WMSM (Western Modern Science and Mathematics) and much of the curriculum we study in these fields represent white, male, patriarchal perspectives (Taylor & Wallace, 2007). Sheth (2019) denotes that in the case of science education, it can "maintain unequal racialized power relations between students and science when historical and contemporary legacies of racism are not directly confronted" (p 37).

Although equity pedagogies have been modeled and researched in science education, they are still a challenge in practice (Braaten & Sheth, 2017). In fact, Archer (2007) discusses the paradoxical nature of science education promoting equality since the various fields within STEM are also promoted in the neoliberal discourse that careers in STEM are more valuable than social science fields since it advances economic development (i.e. capitalism).

Work has begun to reimagine the purpose and curricula of STEM, but considerations of equity in STEM remain narrow and do not include the experiences, worldviews, funds of knowledge, and interests of students from diverse backgrounds (Bianchini, 2017; Wiseman *et al.*, 2020). Undergraduate studies in STEM are largely about career driven actions and do not include ideas around culture, history, or identity. While this is known about K-12 and post-secondary STEM, there is little research on TEPs.

Transitional Education Programs (TEPs)

The term transition is used in reference, for example, the transition from school to work, or from unemployment to re-entering school. Transition programs offer varying supports to enter employment, education or training. Various programs exist that are meant to prepare individuals for their next steps by providing them with further education, credentials, employment training, and other skills building.

Especially for young adults, transitional periods can be a time of uncertainty, economic instability, and mental stress (Arnett, 2000). Programs are necessary to help young adults navigate these difficulties while providing them with potential pathways and opportunities. They are important here in Canada, since adults are increasingly re-entering the formal education system, with nearly 200,000 adult learners returning to school each year (MTCU, 2017). This includes an increase of Black and other racialized students accessing these types of programs. TEPs are meant to give better education access to students.

Despite the need to increase access to post-secondary education, we still do not have research on the effectiveness of TEPs and enrolment of Black students in STEM undergraduate studies (Miner, 2011). While Canadian institutions do have transitional support for marginalized groups, few programs target students in STEM fields (Cooper & Arruda, 2020). Consequently, there is a gap in research in not only the effectiveness of TEPs, but also in gathering stories about Black students' experiences in these programs and knowing whether these programs influence decisions to pursue STEM.

Theoretical Framework

Since race, identity and Black stories are central to this study, Critical Race Theory (Ladson-Billings & Tate, 1995) is appropriate for the analysis. CRT studies a "systematic inquiry about how racial inequities are created and sustained in the lives of ethnic minorities" (Bhattacharya, 2017, p 75). This theoretical framework will illuminate voices of those absent from this discourse – Black student voices on access to post-secondary studies in STEM. Critical theories attempt to move the needle on effecting social change (Birks, 2014) and this research, using CRT to analyse data, will interrogate the institutional and social structures of transitional education programs by highlighting Black stories.

Research Questions

What factors influence Black students' decisions to enroll in/pursue STEM undergraduate studies through a transitional education program?

Research Design and Methods

Scholars have discussed the need for research on the *experiences* of Black students, instead of the use of standard statistics and data on enrollment, grades, performance, etc. alone (McClain, 2014). Thus, this study will employ explanatory a critical case study, bounded by the system of transitional education and shared identity of Black students interested in pursuing STEM. A critical case study focuses in depth stories of participants (Creswell & Poth, 2012).

Data Collection

In a pilot study, I have completed eleven interviews with first year undergraduate Black students interested in STEM. Moving forward, I will conduct roughly the same number of interviews with Black students in Transitional Education Programs. The questions will be written based on the findings from the pilot study and include their experiences, identity, what led them to the program, supports they are using, how they think of themselves in relation to STEM, reflections on transitional education, experiences with race/racism, academic progress, social/mental well-being, and post-secondary pathways. The data analysis will identify emerging themes (Ryan & Bernard, 2003).

After the interviews, I will write reflective research memos. These memos comment on my reactions and experience of conducting the interview and form a set of data that helps to understand the positionality of myself as a researcher, which can inform data analysis (Rogers, 2018). As I conduct the data analysis, I will write analytic memos on the emerging themes. This also constitutes a form of data and can ensure the process of identifying themes triangulates these various data points (Breitmayer, 1991).

Data Analysis

Using critical theories, many truths and meanings emerge because this research acknowledges that there are multiple realities depending on point of view (Creswell & Poth, 2018). This also acknowledges that my own experiences and realities as a researcher, science teacher in TEPs, cis-gendered woman, mother, person of colour, and other intersectional identities will inform the data analysis of this study. (*I am limited by the space in this synopsis, but write at length about my positionality in the thesis*).

I will transcribe audio interviews. This is an important form of re-living the interviews conducted and can assist in identifying codes and themes (Creswell & Poth, 2018). Once transcribed, data will be coded by re-reading transcripts repeatedly. In this method codes are established and colour coded. This can be done electronically in a platform such as Excel or Nvivo, however in my experience, the tactile aspect of doing it by hand gives me a physical connection to the data. Once codes are established, emerging themes are identified (Ryan & Bernard, 2003). Once established, these preliminary themes are reviewed again to make connections, revisions, and analysis on modifications, additions, deletions, or otherwise amendments to the themes. This ensures a rigorous approach and can produce an insightful analysis to map back to the research questions (Bazeley, 2009).

Data Representation as Counterstories

Data will be represented through counterstories, which are "a method of recounting the experiences and perspectives of racially and socially marginalized people" (Yosso, 2013, p 10). They reflect the lived experiences of racialized people and bring about critical consciousness on social and racial injustice.

Preliminary Findings

Emergent themes based on the pilot study indicate three important themes that will inform the next phase of interviews. The first is “family matters” that is, encouragement, social/economic support, and guidance of family are indicators for Black students to pursue STEM. The second theme is “Black on campus” where participants identified having Black faculty and peers in STEM encourage their persistence in this field. The third theme discussed is “I only know what I know” meaning access to informal information sources such as Reddit, Facebook and What'sApp influence decisions such as course selection and planning pathways to continue in STEM.

These findings are preliminary as the next phase of data collection will constitute findings of the doctoral study.

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3.7 Mentor Group 7 | Duinen | 3.7.4

Learning about Boundaries – Sustainable Development as an Interdisciplinary Theme in Teacher Education

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Keywords: Science, Secondary Education, Tertiary Education, Teacher Education, Education for Sustainable Development, Educational Design Research, Sustainable Development

Focus of the Study

"We are on the verge of the abyss" commented António Guterres, Secretary General of the UN, on 19th of April 2021, when presenting the State of the Global Climate 2020 report. It has become abundantly clear that humanity is facing a climate crisis, with disastrous effects all around the globe. Systemic change is necessary in the next 30 years to avert the worst. Education plays a key role as a social tipping point in this change (Otto *et al.*, 2020) and should prepare future generations for the changing world. Lower secondary education is of special interest since a very large portion of students pass through it. Science and technology are at the core of understanding the climate crisis. They bear responsibility as well as provide solutions. Science educators therefore have an important part to play, for example in educating students in climate change more thoroughly (Otto *et al.*, 2020), but also learning students how to deal with the complexity the future will hold.

However, it has proven difficult for education for sustainable development (ESD) to take root in secondary education (e.g., de Wolf & de Hamer, 2015; Het Groene Brein, 2015). Different factors impede this development, such a lack of understanding of subject matter, a perceived low self-efficacy in teaching about complex subjects and differences between teacher identity and teaching traditions in science on the one hand and ESD practices on the other hand (Borg *et al.*, 2012; Pedretti *et al.*, 2008). A logical place to facilitate this development is teacher education, where teachers are trained who will have a high impact in the coming 30 years.

The focus of this study is to better understand how to prepare pre-service teachers so that they will be able to educate for sustainable development, thereby contributing to the necessary systemic change and preparing future generations for what is to come.

Theoretical Background

Teachers play a central role in the teaching process. It is useful to conceptualize teacher knowledge and how it is developed (Park & Oliver, 2008). Building on the work of others, such as Shulman and Grossman, Park & Oliver present a model of knowledge bases consisting of subject matter knowledge (SMK), pedagogical knowledge, pedagogical content knowledge (PCK), and knowledge of context. Teaching about climate change or dealing with the changing world introduces new subject matter knowledge, and to effectively teach subject matter knowledge, a teacher needs knowledge on how to teach this subject matter: pedagogical content knowledge. If teachers are insecure about this SMK and PCK, they will avoid challenges and 'stick to the program', which impedes the introduction of the still developing domain of ESD. The concepts of SMK and PCK are thus of special interest.

As an example of subject matter knowledge, Otto *et al.* (2020) argue for the coverage of climate change issues in education. Covering subject matter on climate change may seem to fit well in familiar teaching traditions in science, such as presenting a highly structured curriculum around well-established facts (Pedretti *et al.*, 2008). However, teaching about climate change issues involves uncertainty, for example in predictions models make and in what may happen when tipping points are reached. Here teachers 'lose control' over the SMK, they can no longer be experts that 'have all the answers'. Furthermore, teachers may encounter denial, hopelessness or apathy (Ojala, 2020). Besides climate change issues, other ideas on subject matter include competencies such as futures thinking, systems thinking and values thinking (Unesco, 2020; Wiek *et al.*, 2016) which are part of traditional science subject matter. All these examples of SMK require specific pedagogical strategies. Therefore introducing sustainability SMK in science curricula also requires the introduction of new PCK.

Introducing PCK for ESD is not straightforward. There are many varied examples of ESD. However, common instructional strategies that aim at the development of problem-solving competencies are structured around socio-scientific issues (e.g. Burmeister *et al.*, 2012; Favier *et al.*, 2021; Frijters, 2016). Not only is this an unfamiliar approach in the teaching tradition of science, many teachers also fear that highly contextualized education diverts attention and time from the subject matter that matters (Pedretti *et al.*, 2008). Furthermore, ideas on how sustainable development itself should be practiced are contested and change over time. For example, one may put trust in (future) technology as a fix, while another may find this trust misplaced and advocate for a more sober lifestyle. Likewise, visions for the goals of ESD differ, ranging from informing students to preparing them to actively transform society (cf. Bencze & Carter, 2011; de Wolf *et al.*, 2018). Concerning these contrasting positions, teachers have to be aware of their own views, in order to make choices in what and how to teach. When teacher make choices about what to teach, teacher identity factors in. Pedretti *et al.* (2008) observed tensions between science teacher identities and ideas about issues-based ESD. For example, pre-service teachers want to belong to and rely on the support of a community of science teachers with little affinity towards ESD. To conclude, when developing PCK, such tensions have to be taken into account, when developing a vision and instructional strategies.

Research Questions

The central research question is:
How can teacher education support pre-service science teachers so that they can develop the necessary SMK and PCK to give substance to ESD in their professional practice?

The following four sub-questions are discerned:
1. What SMK and PCK do science teachers need in order to give substance to ESD in their professional practice?
2. What is the current situation of teacher educators and pre-service teachers regarding this SMK and PCK?
3. How can the education at the teacher academy be designed in a way that fosters the development of this SMK and PCK?
4. What is the extent to which this educational design contributes to the development of this SMK and PCK?

Research Design and Methods

This is an educational design research (McKenney & Reeves, 2018) following the phases of analysis & exploration, design & construction and evaluation & reflection with two iterations. The first implementation has taken place from September 2021 to January 2022. The second follows one year later. The design concerns a compulsory course (10 ECTS) in teacher education in biology, chemistry, geography, physics and technology. The pre-service teachers are studying for a bachelor's degree for teaching in lower secondary education and middle-level vocational education. A group of students, diverse in age and professional background, participates each year. The design team consists of six teacher educators with backgrounds in different disciplines, such as physics education, geography education and educational science, and the researcher. Decisions are discussed until agreement is reached. All members of the design team, except for the researcher, teach the course. Meetings of the design team are recorded in order to register the rationale behind design choices.

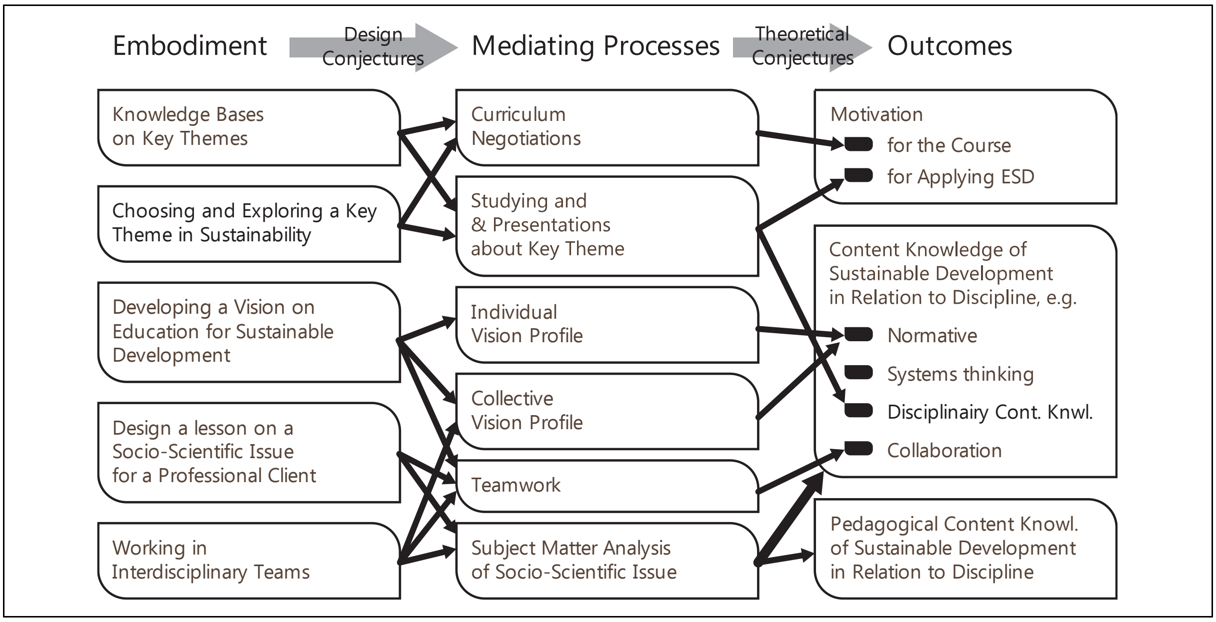

Figure 1. A heavily simplified version of the conjecture map.

Conjecture mapping (Sandoval, 2014) is used to formalize conjectures about the educational design (see Figure 1). Data is collected through different methods. All students are asked to complete a pre- and post-questionnaire. A focus group of around 12 students creates a logbook where weekly questions are addressed. Students of the focus group are interviewed. The course meetings are observed and student artifacts are collected. All data will be analyzed to test the conjecture map. For example, interviews with small groups of students will be coded using elements of the conjecture map and all statements pertaining to specific parts of the conjecture map together will be used to draw conclusions about expectations regarding the educational design.

Preliminary Findings

At the time of this writing data is being collected and it is too early to discuss preliminary findings.

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3.7 Mentor Group 7 | Duinen | 3.7.5

Planning, Delivering and Understanding the Impacts of Environmental Education

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Keywords: Environmental Sciences, Environmental Education, Out-of-School Education, Sustainability Education

Focus of the Study

This research will explore three environmental education (EE) programmes that are differentially situated within the STEM learning landscape, across both formal and non-formal contexts. Using qualitative methods, the study will explore the programmes through the lenses of educator and learner experiences – two perspectives that are rarely considered concurrently in environmental education research (EER). This work will build understanding of how educator strategies translate into learners' experiences, with the aim of contributing to EE practice within science education.

Review of Literature

Education in general, and STEM education in particular, can play an important role in realising a sustainable future. This has been expressed by scholars (Kagawa & Selby, 2009; Scott & Vare, 2018), policy makers (DEFRA, 2019), and international bodies (UNESCO, 2010). Yet, the educational approaches that contribute to this end are many (Scott & Vare, 2018).

Since there are many definitions of EE and its intended outcomes (Scott & Vare, 2018), there are multiple methods within the research field that explore how EE progresses towards its (manifold) goals. A common area of research within EER is to consider the effects of educational practices on learners. Scholars approach this in multiple ways. Trott (2020) adopts a quantitative approach to understanding the effects of a US-based, multifaceted environmental program on learners. Using pre and post-tests, Trott demonstrates increases in learners' knowledge, perceptions and awareness of the environment and climate change. Similarly, Kuthe and colleagues (2020) assess how a diverse group of young people were affected by their involvement in an Austrian environmental project. Their measures consider changes in attitude, personal concern and knowledge alongside behaviour, multiplicative action, and climate change literacy. Research that takes a qualitative approach is useful in offering more descriptive and explanatory results. Stapleton (2019) interviewed young people who had taken part in a climate education trip to Bangladesh from the US and uses the discussions to propose that aspects such as framing climate change as a tangible and immediate problem for humans and their way of life can result in participant reflection and action. Many studies employ either quantitative (e.g. Williams *et al.*, 2021), qualitative (e.g. De Vreede *et al.*, 2014; Birch *et al.*, 2020; Klein *et al.*, 2021) or mixed methods approaches (e.g. Blythe & Harré, 2020; Korfiatis & Petru, 2021) to explore learners' experiences of EE. However, work that purely explores EE from learners' points of view cannot fully take into account how the planning, development and delivery of specific learning interventions interacted with learners' experiences.

For this reason, looking to research which explores how educators' design, develop and deliver EE programmes is an important contribution to understanding the education in this field. Indeed, multiple studies have demonstrated diversity in educators' understandings and approaches to their work in EE in formal and informal contexts. Howard Hunter and Jordan's study (2020) investigated the environmental literacy and self-efficacy of educators. This work recognised that while educators are responsible for engaging learners in activities which are often aimed to increase learners' environmental literacy, educators' own literacy or understandings (and the effects of this on the educational experience) often go unquestioned or unexplored. Glackin's (2016) study demonstrates how educators' perspectives affect the delivery of learning experiences - teachers' underlying beliefs about the nature of learning affected the value they saw in teaching science outside and their ability to successfully lead lessons. Finally, Van Poeck and Östman (2018) use two case studies to demonstrate that educators' choices of 'moves' can create or limit space for learners' consideration and discussion in EE activities. They conclude that there is further opportunity for research to explore how such actions on behalf of educators affect student learning.

Whilst there are multiple studies which explore both what learners take away from EE and what educators' beliefs and practices contribute to EE, there is little research which draws from these two perspectives concurrently, as Van Poeck and Ostman (2018) suggest, to understand how practitioner perspectives and practices interact with learners' EE experiences. My research will build on the work which has mapped and investigated EE learning outcomes, built understanding around educator beliefs and practices, in order to bring these two areas of research into joint consideration. Within this thesis, I plan to develop an understanding of EE from both educators' and learners' perspectives and experiences, to produce findings can be instructive for future environmental education practice and policy. The empirical data collection will explore the EE programmes according to three 'levels' detailed by Rickinson and colleagues (2009). These are the planned curriculum (the intentions of educators and the aims of the programme), the enacted curriculum (what happens in practice - the activities that take place and the communication between educators and learners), and the experienced curriculum (what learners take away or reflect on from the activity). In doing so, my work will build on the under-researched area of exploring EE from both learner and educator perspectives (West, 2015). I foresee that the findings will be useful for educators and policy makers, since they will consider how approaches in planning and delivering EE contribute to experiences for learners.

Research Questions

1. How do EE programme teams conceptualise and consider the role and purpose of their work?
2. What do the activities and messaging in EE programmes communicate about the relationship between people, nature and the environmental crisis?
3. How is this experienced by participants? What do they take away from programmes about their relationship with nature, the environment, the environmental crisis?

Research Design and Methods

This study adopts a critical realist ontology that acknowledges the individuality with which people experience climate change (Cornell & Parker, 2010) and a social constructivist epistemological approach that recognises that knowledge is actively created by individuals through their experiences and social interactions (Dillon, 2003; Cohen *et al.*, 2018; Pring, 2015).

Since my underlying philosophies impress the importance of individual experiences and perceptions, the method I adopt is qualitative, and will explore multiple situated examples through case studies. The data collection will be conducted via observations of learning programmes within case study sites, and semi-structured interviews with both learners and educators at each site, both common data collection methods within case study research (Merriam, 1998; Yin 2009; Cohen *et al.*, 2018). Data analysis will be entirely qualitative, using thematic analysis to draw out emerging common themes from the data (Fereday, 2006; Clarke & Braun, 2017) which can help to inform a model that connects the planning, delivery and experiences of EE.

Preliminary Findings

I have begun data collection on two of my three case study sites at the time of writing and will begin to collect data at my third site in March 2022. All data collection will be finished by July 2022. Following this, I will conduct inductive analysis, in which I will look for themes that emerge from the data.

Currently I have a suggested model that I have developed from initial data observations. This is in the early stages and will be revisited as I gather more data and identify other relevant research. I plan to present this at the ESERA summer school and hope for critique and constructive criticism to aid my revision of it.

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Investigating An Asset-based Approach to Teaching Undergraduate General Chemistry

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Keywords: Chemistry, Tertiary Education, Design-based Research, Asset-based Approaches, Qualitative Methods

Focus of the study

Many universities and colleges in the United States encounter a universal problem of high failure and withdrawal rates in introductory chemistry courses (Bunce *et al.*, 2005; Congos & Mack, 2005). Similarly at our home institution, a diverse public university, up to half of the students do not pass first-semester general chemistry. Because passing General Chemistry 1 (GC1) with a C- or above is required to advance to General Chemistry 2 (GC2), and most STEM majors require two semesters of general chemistry, GC1 has become a "getaway" course preventing students from persisting in STEM. In addition, our university has becoming increasingly diverse, now at 72% systemically excluded racial minorities among undergraduates in the College of Science and Math (CSM). The literature suggests that there is a relationship between diversity of students and DFW rates in STEM getaway courses (Hill & Green, 2007). Predictors of getaway course DFW risk include coming from a low socioeconomic status background, belonging to a systemically excluded racial population in STEM, being a non-native English language speaker, and being a first-generation college student. While knowledge of who is at risk of DFW "is essential to narrowing diversity related achievement gaps and attainment disparities in STEM," (Harper, 2010) it is not sufficient to address the problem. Currently, the predominant form of support for DFW-risk students is remediation of their perceived deficits, such as math or reasoning skills.

Considering that researchers have been calling for use of asset-based frameworks to study systemically excluded students in STEM (Harper, 2010; Rahm & Moore, 2016), we are shifting our focus to learning and building on what is right with our GC1students. This work is part of a larger study that aims to shed light into the ways that an asset-based supplemental chemistry course (CHEM 105) supports academic success in GC1 and beyond for DFW-risk students.

Review of Literature

Scholars have been highlighting the ongoing issue of freshman chemistry becoming an exit point for many systemically excluded STEM students (Stanich *et al.*, 2018). Studies point to several consistent factors that have influence on DFW and retention outcomes in getaway courses such particularly math and general chemistry: self-regulation of learning (Lopez *et al.*, 2013), utilization of academic supports (e.g., tutoring, attending office hours) and development of study groups (Handelsman *et al.*, 2005). Furthermore, studies have shown that students from low socioeconomic status backgrounds often experience forms of culture shock when they arrive to university, because the higher education system is "built and organized according to taken-for-granted, middle- and upper-class cultural norms" (Jury *et al.*, 2017).

Supplemental academic support greatly improves students' persistence and success in initial mathematics and science courses, particularly for students who are systemically excluded in STEM disciplines (Barlow & Villarejo, 2004). Major approaches that take place to provide academic support occur in the remediation of deficits (Augustine *et al.*, 2019; Lee *et al.*, 2018). Studies have shown that those approaches greatly improve students' persistence in STEM introductory courses, however the long-term effects of remediation with students are indistinguishable from no remediation with peer comparisons (Augustine *et al.*, 2019; Bunce *et al.*, 2005). Considering the high increase of failure and withdrawal from general chemistry and the relationship between diversity of students and DFW rates in STEM getaway courses that was pointed out above, there is a clear need for a different approach towards support provided to general chemistry at risk-students. While schools, scholars, and practitioners have been designing initiatives to help at-risk students gain what they "lack", we are using a design-based approach (Collins *et al.*, 2004) to build and study a supplemental chemistry course based on students' assets. Through this study we are interested in understanding the elements of the CHEM 105 course that support students' success as well as how the systems of support at the university contribute to students' success in general chemistry and beyond.

Research Questions

Therefore, the present study is guided by two research questions:

1. Which elements of the embodiment of the supplemental chemistry course design are productive in supporting student success in general chemistry, and how so?
2. How does the system of supports at the university function toward participants' negotiation of challenges and cultivation of meaningful relationships that support their academic success?

Research Design & Methods

Theoretical & Analytical Lens

One of the primarily goals of this work is to understand how and why at-risk students succeed and to identify the systems of support that they rely on. Thus, this research draws on the various theoretical perspectives from which the Anti-Deficit Achievement Framework for Students of Color in STEM is based on (Harper, 2010). The framework is concerned primarily with the research questions that are being asked by researchers in a study and emphasizes the importance of investigating how and why certain populations of students succeed in STEM despite the many challenges they must overcome. We recognize this importance, and we bring this lens into our data collection strategies and analysis to address the research questions of the study.

As previously noted, we are utilizing a design-based approach for this work. In the process of designing the CHEM 105 course, Sandoval's conjecture mapping was utilized (Sandoval, 2014) prior to implementing the course as a means of specifying theoretically salient features of the course design and mapping out how they are predicted to work together to produce a desired outcome. Sandoval suggests building a conjecture map before implementation of the intervention and re-evaluation of that initial conjecture map after the intervention has been implemented. A conjecture map consists of embodiments, mediating processes and outcomes. For the purpose of this work, we have been utilizing conjecture mapping as an analytical tool to look at the students interviews in order to get an understanding of what the students find supportive and helpful about CHEM 105. Additional information on how conjecture mapping is used as an analytical tool can be found in the data analysis and preliminary findings section of this synopses.

Data Collection

To answer the two research questions this work has multiple streams of qualitative data: (1) interviews conducted with students enrolled in CHEM 105 at the end of the semester; (2) interviews with from institutional officials responsible for supporting students in GC1; (3) weekly diary entries from the CHEM 105 instructors and learning assistants reflecting on what they learned about their students that week. We have conducted 54 students interviews across fall 2020, spring 2021, and fall 2021 semesters, as well as 15 interviews with institutional officials. Instructor diaries were collected from 5 graduate student instructors who taught the course and 10 undergraduate learning assistants.

Preliminary Findings

To attend to our first research question, we are making use of conjecture mapping (Sandoval, 2014) to analyze students' interviews. Since we are interested in pointing out the elements of the embodiment of the supplemental course that support students, we coded the CHEM 105 embodiments that students mentioned were helpful to them, the mediating processes that those embodiments lead to and the resulted outcomes. Throughout this process of using conjecture mapping to code students' interviews, we are aiming to operationalize the definitions of embodiment, mediating process and outcomes to be reflective of our own student data. Preliminary findings from students' interviews show that certain embodiments such as the panel of advanced peers that takes place twice in CHEM 105, the nurturing and supportive attitude of the instructors, the multimodal strategies utilized for problem solving and others have been incredibly supportive for students. While moving forward with this analysis, we are aiming to utilize the diaries collected from the course instructors and learning assistants to better understand students' experiences in CHEM 105.

To attend to our second research question, we are currently utilizing content analysis (Mayring, 2014) to analyze the interviews conducted with institutional officials responsible for helping GC1 students succeed in chemistry so that we can better understand how the systems at the university function to support students. Through this preliminary content analysis four main categories have developed: 1) challenges that students face, 2) assumptions that these individuals have about students, 3) advice for students, and 4) recommendations for change at the university level.

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3.7 Mentor Group 7 | Duinen | 3.7.7

Paving the Way through the *'Literacy Jungle'*: Science Education in the Context of Social Media and Climate Change

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Keywords: Chemistry, Secondary Education, Literacies, Social Media

Focus of the Study

Today's society is facing anthropogenic climate change (ACC) as a major challenge of the 21st century. Over 95% of the scientific community agree about ACC (Anderegg, 2010), but a public discourse about this consensus and the complex, interdisciplinary scientific phenomena of ACC has risen, not at last in social media (SM) (Lewandowsky, 2019). This climate change discourse (CCD) gets heated by the spread of misinformation (Howell & Brossard, 2021). To understand the phenomena of ACC, to pursue and engage in the CCD, to make responsible decisions and develop pro-environmental behaviors, citizens need to be informed and scientifically literate (e.g. Bybee, 2009). Therefore, future science education is responsible to empower students through *literacies* in the context of the CCD on SM and enable them to decide on which information they can trust to become informed and reflective citizens (Howell & Brossard, 2021; OECD, 2017).

Concerning this challenge, several *literacies* were defined in science and media education focusing either on scientific competencies (*scientific literacy*, Bybee, 2009) or on online information (*media literacy*, Cooper, 2011). Being aware of the need for re-conceptualizations in science education in the digital era (Höttecke, 2020), research literature combining both perspectives is still scarce. Additionally, social networks as informal learning environments might foster student's motivation to adopt pro-environmental behaviors (e.g. Robelia, 2011), but it is still unknown if those behaviors are already defined in the numerous *literacies* and how they can be developed. Since ACC mitigation requires the development of literate behaviors, this study shall pave the way through the '*literacy jungle*'.

Addressing these research gaps, a systematic review is conducted on *literacies* that are potentially relevant in the context of the CCD on SM. Within the review all *literacies* are compared, through the lens of the *Integrated Behavioral Model* (IBM), based on their defined behaviors of a literate human. The review finally focuses on the extent to which *literacies* define behaviors to deal with information as a reflective citizen confronted with the CCD on SM. An upcoming longitudinal study based on the review results will examine the *literacies* that 10th and 11th grade students, respectively, develop and how they use them to search for, perceive and interact with, organize and critically reflect information in the context of the CCD on SM. The whole research project is located in biology, chemistry and physics education to cope with the interdisciplinary nature of ACC and compiling results will propose implications for future science education.

Theoretical Background

Educators are facing many challenges teaching about ACC and its complex scientific phenomena. To cope with these challenges, *scientific literacy* is the primary concept for evolution of scientific knowledge, competencies and skills. Through student's factual knowledge, their attitude towards science and understanding of Nature-of-Science (NOS), they should be enabled to engage with socio-scientific issues, such as ACC, in their everyday life's (Bybee, 2009). Because of today's shift away from traditional science communication towards SM, a change of traditional NOS is considered (Höttecke, 2020). Students perceive environmental information from online media and need to ensure the credibility of the scientific information they receive. The mitigation of ACC further requires climate change education, that increases student's awareness and engagement and is adapted to digital environments (Duran-Becerra, 2020; Monroe, 2019; Bhattacharya, 2021). First approaches towards this adaptation are definitions of *science media literacy* (Höttecke, 2020) and *digital media science literacy* (Howell & Brossard, 2021). However, the question remains which behaviors those *literacies* exactly propose and how much they differ from other *literacies* that are potentially relevant in the CCD on SM like *climate literacy* (Alkaher, 2020), *environmental literacy* (McClaren, 2019) and *information literacy* (Lloyd, 2005).

The IBM is a derivative of the Theory of Planned Behavior (TPB) (Ajzen, 1991). The TPB characterizes behavior based on the behavioral determinant (BT) "Intention". Fishbein extended the TPB and developed the Integrative Model of Behavioral Prediction (IMBP) (Fishbein, 2000) further including "Skills" and "Environmental Constraints" as BTs. The IBM adds "Knowledge", "Salience" and "Habit" to the IMBP and – in distinction from the TPB and IMBP - is chosen for its ability to characterize behavior based on all five BTs (Kasprzyk & Montano, 2008). From the perspective of science education, "Knowledge" could be a prior determinant when predicting student's literate behavior (*scientific literacy*). In the context of SM, "Habits" and "Salience" could be precursors for media usage and online interaction with ACC information.

Research Questions

Systematic Review

The systematic review and the application of the IBM on *literacy* definitions address the research questions (RQ 1 & RQ 2) underlying the further study evaluation. All *literacies* are exclusively investigated in the context of the CCD on SM:

1. How can the *literacies* be compared using the IBM?
2. Which behavioral determinants and behaviors do the *literacies* define?

The further elucidation of defined behaviors in the context of student's perception of online ACC information, will be guided by RQ 3. All ACC information are exclusively investigated in the context of the CCD on SM:

3. To which extent do *literacies* define behaviors potentially relevant to search for, perceive and interact with, organize and critically reflect information?

Longitudinal Study

The longitudinal study will be guided by RQ 4 – RQ 6 and addresses the individual development of *literacies* of T1=10th (T2=11th) grade students and their information behavior on YouTube, as exemplary social media platform. All *literacies* will exclusively be investigated in the context of the CCD on SM:

4. Which potentially relevant *literacies* can be observed for 10th (11th) grade students and do they develop over time?
5. How do 10th (11th) grade students search for, perceive and interact with, organize and critically reflect ACC information on YouTube?
6. To which extent are student's *literacies* and information behavior cross-correlated over time?

Research Design and Methods

The whole project design including the systematic literature review and the longitudinal study (T1 and T2) is shown on the timeline presented in Figure 1.

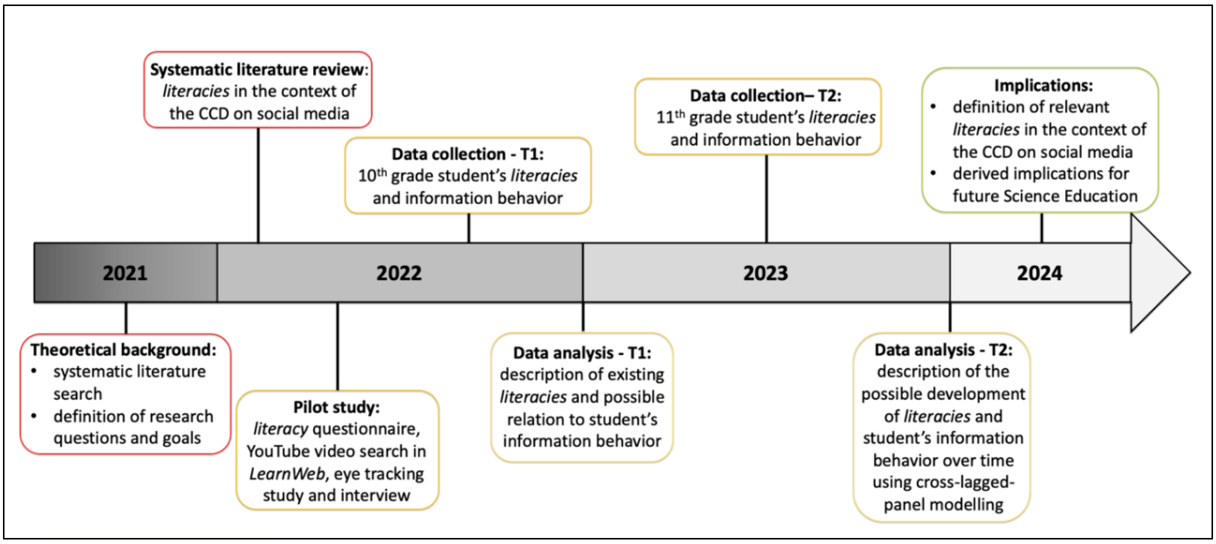

Figure 1. Timeline of the whole project design.

Systematic Review

The systematic review is conducted according to the PRISMA statement (Page, 2021) and literature investigation of potentially relevant *literacies* from science and media education, information technology and psychology. The systematic search is performed in 5 databases (Web of Science, ERIC, Wiley online, Taylor & Francis, Springer Link) from Jan to Feb 2022. For the comparison of *literacy* definitions using the IBM a coding with MAXQDA is conducted. Besides the deductive behavioral determinants of the IBM, inductive subcategories from *literacy* definitions were included in the framework where needed for proper comparison.

Longitudinal Study

The longitudinal study will start mid 2022 (T1) by collecting data from 250 German 10th grade students and will be finished mid 2023 (T2) collecting data from the same students. The study will include three settings and use an internally developed environment, *LearnWeb*, as search and sharing platform combining several search engines with the possibility to save relevant content:

- *Literacy* questionnaire that surveys student's individual *literacies*.
- Individual YouTube search for ACC content via *LearnWeb* that surveys student's information behavior. Eye tracking will show where students looked at completing the *LearnWeb* task.
- A semi-structured interview will guide students through critical reflection of their task completion.

The qualitative data will be analyzed via content analysis and quantified for the further analysis. The quantitative data will be incorporated in a cross-lagged-panel model to reveal possible interactions of student's *literacies* and information behavior over time as well as possible correlations of both indicators at T1 and T2, respectively.

Preliminary Findings

The systematic review revealed which behaviors are defined in *literacies* in the context of the

CCD on SM and how students can develop those behaviors. In addition to this, the review illustrated, to which extent *literacies* from different research fields propose similar behaviors that are claimed as relevant for informed and scientifically literate citizens in the 21st century.

For the first data collection point (T1) of the longitudinal study that will be located before the ESERA summer school, we expect quantitative data for 10th grade student's Literacies and information behavior on SM based on eye tracking, clicks, mouse movements, search terms and relevance ratings. In addition to this we expect qualitative data from the interviews.

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4 Face Book

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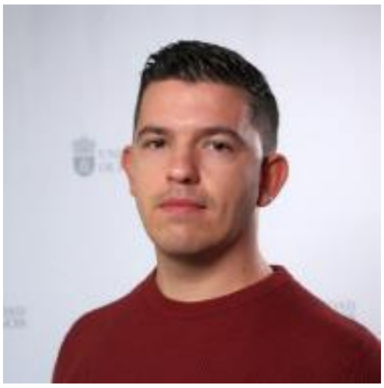

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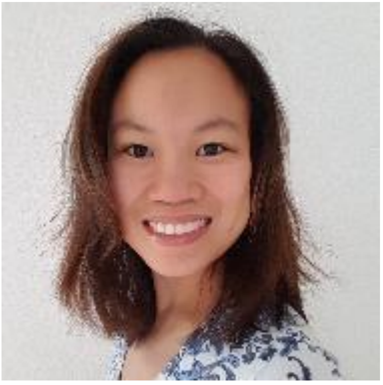

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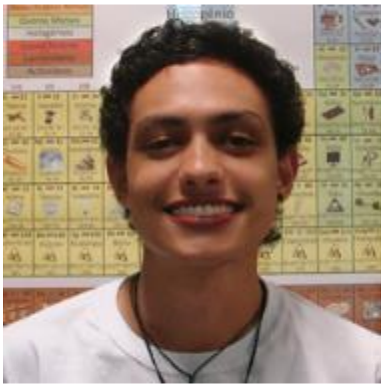

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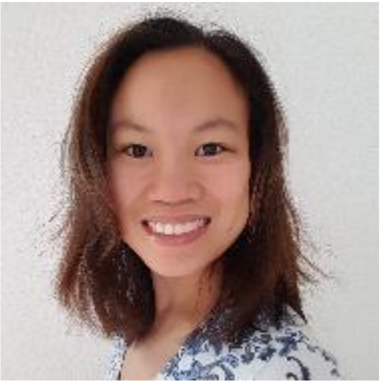

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