Mikhail Fominykh and Maria Aristeidou (Eds.)

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning

co-located with the Sixteenth European Conference on Technology Enhanced Learning (EC-TEL 2021)

Virtual Event, Bolzano, Italy, September 20–21, 2021

Program Committee of the Doctoral Consortium

Maria Aristeidou, The Open University, UK

Ana Benavides Lahnstein, Natural History Museum, UK

Tim Coughlan, The Open University, UK

Monica Divitini, Norwegian University of Science and Technology, Norway

Mikhail Fominykh, Norwegian University of Science and Technology, Norway

Davinia Hernández-Leo, Universitat Pompeu Fabra, Spain

Garron Hillaire, Massachusetts Institute of Technology, USA

Ralf Klamma, RWTH Aachen University, Germany

Roland Klemke, Open University of the Netherlands

Birgit Krogstie, Norwegian University of Science and Technology, Norway

Birgy Lorenz, Tallinn University of Technology, Estonia

Kalpani Manathunga, Sri Lanka Institute of Information Technology

Daniele di Mitri, Leibniz Institute for Research and Information in Education, Germany

Ekaterina Muravyeva, Open University of the Netherlands

Zacharoula Papamitsiou, Norwegian University of Science and Technology, Norway

Khalid Md. Saifuddin, Technical University of Denmark

Mar Pérez-Sanagustín, Computer Science Research Institute of Toulouse, France

Mohsen Saadatmand, University of Helsinki, Finland

Maren Scheffel, Ruhr University Bochum, Germany

Jan Schneider, Leibniz Institute for Research and Information in Education, Germany

Natalia Spyropoulou, Hellenic Open University, Greece

Fridolin Wild, The Open University, UK

Preface

The EC-TEL Doctoral Consortium is part of the EC-TEL since its beginning in 2005. The Doctoral Consortium is part of the doctoral program of the European Association of Technology Enhanced Learning (EATEL). Besides the Doctoral Consortium this program comprises the JTEL Summer School for doctoral candidates. Together, these two events have been shaping and enriching the experiences of many young researchers in their PhD journey and building a community that focuses on and solves the transdisciplinary challenges of our field.

This volume contains papers presented at Doctoral Consortium of the Sixteenth European Conference on Technology Enhanced Learning (EC-TEL 2021) held on September 20–21, 2021 in Bolzano, Italy, as a fully online event. There were 20 applications, of which 15 resulted in full paper submissions. Each of the 15 papers have been reviewed by three doctoral consortium committee members. All 15 submissions were found eligible for presentation at the doctoral consortium. The papers in this volume completed the full reflection cycle that is characteristic for the EC-TEL Doctoral Consortium.

The EC-TEL Doctoral Consortium is designed as a training event for PhD candidates that seeks to improve the quality of their research. This starts with expressing the own research project and with identifying the limitations and challenges of the present stage. These initial submissions were reviewed by the program committee of senior members of the community. In order to strengthen the learning experience, every doctoral candidate who participated in the event had to review one other submission and raise questions. Together the reviews provide the foundation for the presentations at the Doctoral Consortium, which were then discussed and challenged by the board of experts. Besides paper presentation, the doctoral consortium included a keynote, a social interaction session, mentoring session, and short workshops. After the Doctoral Consortium all participants had the opportunity to present their work as a poster at the main conference, which creates a unique opportunity to engage into discussions with the wider research community. All papers included into these proceedings have been reworked to address the comments of the reviewers and the participants of the event.

The submissions to this year's doctoral consortium show the continued relevance for PhD candidates to get qualitative feedback on their projects beyond the level of research papers. Receiving submissions from seven countries across Europe, the EC-TEL Doctoral Consortium shows its international relevance. The variety of topics with both technological and educational focus represented at the doctoral consortium once again highlight the highly multidisciplinary nature of the TEL field. This is complemented by EATEL's activities for building the doctoral community including the series of webinars organized by the DETEL EU project.

31 December 2021
Mikhail Fominykh

Contents

Learning analytics supported goal setting in online learning environments

Gabrielle Martins Van Jaarsveld[a], Jacqueline Wong[b], Martine Baars[a], Fred Paas[a], Marcus Specht[b]

[a] *Erasmus University Rotterdam, Burgemeester Oudlaan 50 3062PA, Rotterdam, The Netherlands*
[b] *Delft University of Technology, Mekelweg 5 2628CD, Delft, The Netherlands*

Abstract
The rapidly increasing role of technology in education has resulted in large amounts of data being collected about student learning and behavior, and as a result, has given rise to the field of Learning Analytics. Although much research in this field has focused on offering insights to educators, researchers have suggested learning analytics may be most effectively employed when they focus on insights which can be offered directly to students. Furthermore, researchers have called for more focus on research driven by educational theory and given the highly self-directed nature of higher education in general, and online learning environments specifically, self-regulated learning can be highlighted as an important theoretical framework to consider in future studies. Self-regulated learning (SRL) can be viewed as a cyclical process in which goal setting and monitoring play an integral role in driving behavior, and prior research has shown that SRL skills are positively related to academic performance. However, prior research on how learning analytics can support goal setting to enhance SRL is extremely scarce. The aim of this project is to explore the question of how learning analytics can support the goal setting process in online learning environments to improve SRL and performance? In this project several studies have been designed to (a) examine the effectiveness of a learning analytics supported goal setting and monitoring tool to improve academic performance, (b) consider the influence of individual student characteristics on the effectiveness of this learning analytics tool (c) consider whether personalizing learning analytics tools to support goal setting can increase the efficacy of the tools. Overall, the aim is to be able to offer guidelines for how learning analytics tools can be designed and personalized to increase the effectiveness of goal setting interventions to optimize SRL and performance in online learning environments.

Keywords 1
Goal setting, self-regulated learning, learning analytics, technology enhanced learning, personalized interventions

1. Introduction

The past few decades have seen some major changes within the field of higher education, and a fast-paced move towards digitalization has changed the way a lot of education is carried out. This shift has brought about changes on two fronts; firstly, technology enhanced learning (TEL) has become increasingly commonplace in traditional face-to-face education, and Information Communication Technology (ICT) is now a standard addition to the day-to-day learning activities of the average higher education student [1]. Secondly, there has been a rise in new forms of education, which are either partially online, called blended learning, or

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: martinsvanjaarsveld@essb.eur.nl
ORCID: 0000-0002-1864-8978

fully online, like distance learning or massive open online courses (MOOCs). While these kinds of education have been on the rise for several decades, the past few years have seen them become more widely available and accessible to a larger audience. This shift has offered the opportunity to expand and grow both research and educational practice in many novel directions. However, this shift to partially or fully digital learning environments has also brought about some unique difficulties. It has become clear that the skills needed to thrive in these digital learning environments are not always the same as those needed in traditional face-to-face classrooms [2], [3]. This has been highlighted during the COVID-19 pandemic, where the sudden and widespread shift to digital education saw a lot of students struggling to effectively manage their own learning [4]. This struggle has highlighted the fact that some of the most important skills needed to thrive in TEL environments are self-regulated learning (SRL) skills. According to researchers, throughout their years in higher education “students are on a journey to become self-managing and self-directed learners.” [5, p. 130]. While they may be important in any higher education program, SRL skills are even more important in TEL environments, which often involve high learner autonomy, less teacher oversight, and a non-linear program structure [6]. SRL is described as a process in which students are metacognitively and behaviorally active in their own learning process, and implement self-monitoring, learning, and reflection strategies to strive towards goal attainment [7]. As higher education continues its current trend towards digitalization, supporting students in their development of SRL skills is likely to become even more critical to ensure their success.

Understanding how to support learners SRL is a topic which has garnered much attention from researchers over the years [8]–[10]. Previous research has shown that high SRL skills are a predictor of effective learning processes, and better academic performance [11]. Furthermore, research has shown that many students lack effective SRL skills, and struggle to implement SRL strategies within their daily learning processes [12]. However, effectively supporting SRL, especially within online learning environments, has been shown to be a complex task [6], [13], [14]. Previous studies have demonstrated that student engagement with SRL support tools is often low [15], [16], and those students who are most in need of support are often the ones least likely to seek it out and make use of it [17], [18]. Furthermore, tools which are developed to support SRL differ widely in their approach and content, and as such, they are not all equally effective. Some SRL support tools are significantly more likely to result in behavioral change and have positive effects on academic outcomes than others [19]. Moreover, not all students interact with SRL support tools in the same manner, and what is effective for one group of students might not be as effective for other groups [20], [21]. Thus, it is important to fully explore how to effectively design and implement SRL support tools within TEL environments, as well as how to tailor them to the needs of individual students and increase the likelihood of students engaging with them.

1.1. Self-regulated learning and goal setting

SRL is a broad framework which describes several motivational, cognitive, and behavioral processes which contribute to an autonomous learning process [7]. These processes have been extensively studied, and as a result, there are many different models which have been proposed to describe them (for a review see [22]). The most commonly used model of SRL is that by Zimmerman [23]. Zimmerman described SRL as the process of transforming mental and physical abilities into task-related skills [7]. Zimmerman’s model describes the process as cyclical, with three separate stages: 1) the forethought stage, 2) the performance stage, 3) and the self-reflection stage. Students start in the forethought stage by setting goals and creating plans to achieve them. In the performance stage they use regulatory strategies to guide their study activities and monitor their progress towards their goals. And finally in the self-reflection stage they reflect on their performance, and how well they have achieved their goals and adjust their plans for future learning accordingly. While it is important to support students throughout the whole SRL process, the first stage, goal setting, is especially critical as it drives the rest of the cycle and forms the basis for motivated behavioral change [24]. A goal is defined as “something an individual is trying to accomplish" [25, p. 126] and goal setting is the act of consciously deciding upon goals to strive for. Without effective goal setting, students are not able to effectively carry out the second and third phases of the SRL cycle. This highlights the importance of understanding the underlying processes of the SRL cycle in order to support it. Self-determination theory (SDT) describes the elements which drive motivated behavior [26]. According to SDT the three crucial elements for motivation are autonomy, competence, and relatedness [26]. The importance of allowing students autonomy within education has been demonstrated [27], and the importance of autonomy within SRL has also been established [28]. Prior studies show that while TEL tools may try offer students autonomy in how they use them, the decisions students make may not always be the most effective for learning or performance [14]. It therefore becomes clear that in order to design an effective goal setting intervention, the goal setting process should be guided sufficiently for students to set effective goals, while still allowing students to feel autonomous and motivated in the process.

Goal setting as a means of improving performance has been studied for many decades, starting with Edwin Locke who developed the Goal Setting Theory [29]. Locke's original theory focused on how goal specificity and goal difficulty moderated the relationship between goal setting and task performance [29]. Goal setting has remained a popular research topic, and research over the years has suggested many other goal characteristics which may affect effective goal setting. However, despite a broad base of literature on the topic, there is very little consensus on what the characteristics of an effective goal setting tool are. Prior research does show that there is a delicate balance that needs to be struck between guiding students to set effective goals and giving them autonomy to create their own goals. Studies show that students are generally ineffective goal setters when allowed to set their own goals [30], [31]. However, merely having a goal in mind is not enough, the kinds of goals which are set as well as the act of creating plans to achieve them are also important [32], and therefore providing guidance is crucial.

Furthermore, although some studies in recent years have started to carry out goal setting activities in online learning environments, there has been very little research on the potential to enhance and support these tools when they are delivered digitally. To support the process of SRL in TEL environments, tools can focus on helping students set effective and meaningful goals, and then offer additional support to guide them through the remainder of the SRL cycle. However, SRL interventions can be resource heavy, especially given the fact that they are often most effective when they can be adjusted to the needs of individual students. TEL environments can offer personalized and adaptive interventions by making use of data collected about student performance and behavior, which is known as learning analytics. Therefore, offering support tools in TEL environments have a unique advantage in using learning analytics over traditional face-to-face classrooms.

1.2. Learning analytics

Learning analytics is still a new area of study, which arose as TEL became more common in day-to-day educational settings. The definition of learning analytics still differs across the literature, but The Society for Learning Analytics Research defines it as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments" [33]. This definition covers a broad range of data and analysis opportunities which have arisen within education. Learning analytics relies on data which is generated when students interact with digital learning environments, and this is called trace data [34]. Trace data are interpreted as observable indicators of students' underlying learning processes [35]. Thus, the aim of learning analytics studies is often to draw conclusions about learning processes based on how students behave in online learning environments. While researchers have previously theorized that learning analytics offer a powerful and efficient means of supporting SRL [36]–[38], few studies have implemented learning analytics as a means of enhancing and personalizing goal setting tools [9]. Furthermore, while prior research has shown that student engagement in online learning environments can be a challenge, learning analytics and technology in general offer means of combating this problem. SRL tools in online environments can combat low engagement by offering personalized experiences using learning analytics data. Personalization in education, and within the field of TEL tools is a popular topic, but it's important to understand in what ways personalizing tools using learning analytics can be beneficial. There are many different characteristics which affect the way in which students interact with TEL environments, such as personality traits [39], [40]. In the context of learning analytics, personalization can include identifying groups of students on the basis of their individual characteristics, examining what their patterns of use reveal about their interaction with the tool, and their individual needs, and creating a tool which is adaptive in nature can be personalized in response. While this kind of personalization can take many forms, the aim is to create a tool which moves away from the one-size-fits-all approach of educational tools, and to take advantage of the affordances offered by TEL tools.

Another powerful means of leveraging technology and data to support goal setting is using conversational agents. Prior studies have shown that goal setting guidance is significantly more effective when delivered by an experimenter, as opposed to via a worksheet [41]. Furthermore, it has been suggested that conversational agents could significantly improve the effectiveness, and scalability, of goal setting based interventions [42]. Existing studies have shown that conversational agents can have a positive effect on student engagement with the tools, as well as increasing their effectiveness [43]. However, there is little experimental work on the effect of delivering goal setting interventions via conversational agents. This demonstrates the power of leveraging learning analytics and TEL environments to enhance SRL tools to increase their effectiveness, but also the gap in the literature about effective means of doing so. These methods of creating adaptive and personalized interventions are especially important given that current literature suggests that not all students interact with learning analytics tools in the same manner, and it is therefore important to offer individuals personalized experiences to maximize their benefits [44], [45]. Given the literature which suggests that that individual student characteristics affect the way in which students interact with these tools, and it is therefore important to take this into consideration and create adaptive tools which can adjust to the needs of individuals [9], [46].

Therefore, during this project we aim to address the importance of SRL in TEL environments, by investigating how to best design and implement goal setting support tools, enhanced by learning analytics, to improve student SRL skills and academic performance. We aim to use learning analytics to not only offer personalized goal setting, monitoring and reflection tools, but also to create a tool which adapts based on a student's prior performance, and personal characteristics.

2. Proposed approach

With this project, we aim to apply a multidisciplinary approach by combining insights from the fields of psychology, educational sciences, learning analytics, and educational data mining. Figure 1 below shows an overview of the studies planned for this project. Overall, with this project we aim to understand how best to implement goal setting and monitoring tools in online learning environments, and to explore how learning analytics can be used to enhance and personalize them, to offer students support that is tailored to their individual needs. The main research question of this project is "How can learning analytics support goal setting in online learning environments to improve learning and performance?" We will attempt to address this question using a design-based research approach, in which we develop a learning analytics supported goal setting tool, which is then implemented, tested, and refined in an iterative process. During each study carried out in this project, the developed tool will be tested in real-life educational settings and refined and improved based on the findings during that study. Each study will build upon the findings of the previous study in an iterative process aimed at improving the effectiveness of the tool and expanding its functionality with each study. During studies 2-4 the learning analytics supported goal setting tool will be embedded in a learning management system (LMS), used by students carrying out their bachelor's degree within a large Dutch higher education institution. Students will be able to interact with the directly from their browser while using their

LMS. Student performance will be measured using course grades, and trace data about student performance and behavior will be drawn from the LMS, as well as the learning analytics tool directly.

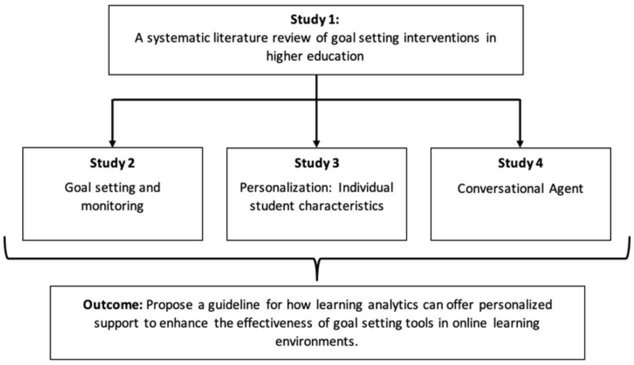

Figure 1. Overview of planned studies in project

2.1. Study 1: literature review

The first study will be a literature review, which will give an overview of the field and existing relevant literature. This will culminate in the development of a goal setting tool, which will be used in later studies. The research questions for this study are as follows:

1. How have guided goal setting interventions been carried out in previous studies in higher educational institutions?
   1.1. What kinds of goals are students guided to set?
   1.2. How are the interventions designed and implemented?
2. What is the effect of the guided goal setting intervention on academic performance and SRL skills?
3. How has technology, and learning analytics been used to support goal setting in prior studies?

This study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement to carry out a systematic search of the relevant literature [47].

2.2. Study 2: goal setting and monitoring

Study 2 focuses on developing and implementing the goal setting tool, alongside learning analytics support in the form of goal monitoring and reflection elements and testing what effect the tool has on SRL skills and academic performance. The research questions for this study are as follows:

1. What is the effect of goal setting interventions on self-efficacy, self-regulated learning, and student performance in an online learning environment?
2. How can real time goal monitoring supported by learning analytics enhance the effect of goal setting interventions on student performance and engagement in an online learning environment?

This tool will be designed based on findings from the literature review carried out in study 1, as well as on theory from the relevant fields. Study 2 will be a randomized controlled trial (RCT) with two types of goal setting interventions and a control group. Analyses of Variance (ANOVAs) will be used to test whether the experimental groups differ in performance after the intervention tool has been used for a semester, and repeated measured ANOVA will test whether there is a difference in pre- and post-intervention self-efficacy, engagement, and SRL. Throughout this project Zimmerman and Pintrich's models of SRL will be used to evaluate the interventions and SRL skills [22]. Trace data will be examined to identify patterns of behavior in the learning environment and when using the tool, to inform the design of future iterations of the tool. This step is more exploratory in nature and will be used to inform decisions made during Study 3.

2.3. Study 3: personalizing SRL tools

Study 3 focuses on individual student characteristics, and how the goal setting tool can be personalized using learning analytics, to increase its effectiveness. The research questions for this study are as follows:

1. To what extent are the effects of goal setting and monitoring interventions

moderated by individual student characteristics?
2. How can personalizing learning analytics tools based on student characteristics improve their effectiveness?

This study takes place in two parts. The first part will follow a similar design to study 2, but with a focus on testing the effectiveness of the tool, and students' interaction with the tool based on their individual characteristics. The second part aims to personalize elements of the intervention and examine whether this personalization improves the tools effectiveness. This personalization will be based on the exploration of groups of students and their patterns of behavior from Study 2, as well as existing theory and literature, and will focus on characteristics like personality traits, maladaptive study behaviors (like perfectionism or procrastination) and prior performance. The effectiveness of the tool will be tested in an RCT using an ANOVA to compare experimental groups.

2.4. Study 4: SRL supporting conversational agent

Finally, study 4 focuses on how to increase student engagement with the tool, by testing its implementation in the form of a conversational agent. The research questions for this study are as follows:

1. How does delivering the learning analytics supported goal setting tool via conversational agent affect engagement, self-efficacy, and student performance?

This study will follow a similar layout to Study 2 and 3 and will test the effectiveness of the tool when it is integrated with and delivered by a conversational agent. We will then examine whether this improves the effectiveness of the tool by examining differences student performance in a RCT. Patterns of student engagement with the tool will also be examined.

3. Current results

Currently, study 1 has been carried out. This is a systematic literature review of goal setting interventions in higher education settings. In this study, a systematic literature review was carried out following the PRISMA guidelines, and we aimed to examine all papers published after 2010, which had an active academic goal setting tool that was implemented amongst higher education students. The final sample included 37 papers. The final sample of papers were then examined, and the goal setting tools presented in them were broken down into various characteristics covering two main areas: 1) the intervention implementation and design, 2) the characteristics of the goal setting activity.

Regarding the intervention implementation and design, the results showed that less than half of the papers (n = 16; 43%), were experimental designs which tested the effectiveness of the intervention. This means most of the papers were implementing goal setting activities without testing whether they were having the intended effect on student behavior or academic performance. This result may seem surprising given previous studies showing that not all goal setting activities are effective at bringing about behavioral change [48], [49], however prior work has noted the gap between educational theory and what researchers want to measure, and the implementation of TEL tools [50].

Furthermore, the results showed that while the interventions were delivered digitally in almost half of the papers (n = 17; 46%) of, for the most part, these interventions had no form of technology support or enhancement and were neither personalized nor adaptive. Instead, most digitally delivered goal setting interventions were merely computer-based versions of a static pen and paper type intervention. This made it clear that while there is a definite shift in SRL interventions towards digitalization, at the current time most tools do not make use of the full potential of technology to improve or support their interventions.

Regarding the characteristics of the goal setting activities, several elements were examined including goal type, goal context, goal depth, and goal distance. Overall, what could be seen from this examination was that in general, goal setting interventions offered very little guidance as to the kinds of goals students should be setting. It was observed that students were asked to set goals, but not given any specific characteristics or content that their goals should contain in most studies. While this allows for a lot of student autonomy, it is troubling in the face of prior research which shows that when unguided, students generally don’t set very effective or meaningful goals, and that some types of goals are more effective at bringing about behavioral change than others [51].

The focus on unguided forms of goal setting, and non-experimental designs in the studies reviewed makes it hard to draw conclusions regarding the most effective way of scaffolding goal setting. However, the results did suggest that delivering interventions digitally, combining goal setting with support for other stages of the SRL cycle, and requiring that students set more detailed, specific goals were all associated with goal setting having a positive effect. From these results, it is clear that more studies are needed to actively examine the characteristics of effective goal setting interventions.

Taken together this suggests several things for the future of this project; 1) there is a disconnect between the existing literature on how to set effective academic goals, and the development of many of the goal setting tools implemented in previous literature. And 2) while these kinds of interventions tend to be delivered digitally, there is a lot of room for improvement in how technology and learning analytics can be used to support and enhance these tools.

4. Contribution to TEL domain

While the TEL domain has been around for several decades, the last decade has seen a massive increase in its popularity in the average higher education classroom. As such, it is more important than ever to address how to best support students while learning in TEL environments. This project contributes to the understanding of how learning analytics can be efficiently implemented to support student SRL in online learning environments. It focuses on bridging the current gap in the scientific literature between learning analytics implementation and educational sciences theories. This project will also build on the literature available about the SRL cycle in academic environments and offer insight into how this process motivates behavioral change, and how this can be further supported in online learning environments. It will go on to explore how learning analytics and conversational agents can be used to enhance goal setting interventions in TEL environments in order to make them more engaging and better tailored to the individual needs of students. With the results from this project, we aim to advance the understanding of how to best implement goal setting support tools within online environments, to help enhance students’ SRL skills that are needed to succeed in an increasingly digital educational landscape.

While this project has wide-reaching scientific significance, it also has important practical significance. It will focus on using education sciences theories to shape learning analytics tools and offer insight into the role of individual student characteristics in shaping the way students interact with learning analytics tools. These insights can be used to form the basis of future research into, and development of, learning analytics tools. The rise of technology enhanced learning has highlighted the need to create tools which can support students learning in online environments in a personalized manner. The studies in this project aim to understand how learning analytics tools can best offer this support, and to create guidelines for the development of these tools in the future.

While several studies have examined the use of learning analytics to support performance, very few have focused on the use of learning analytics tools to support goal setting and goal monitoring. Furthermore, there is currently very limited research on how individual student characteristics like perfectionism or self-efficacy affect the way students interact with learning analytics tools, and to what extent these tools are effective for students who differ on these characteristics. This project aims to develop tools which can be used to offer personalized learning analytics supported SRL tools.

5. References

[1] J. T. Schmidt, M. Tang, Digitalization in Education: Challenges, Trends and Transformative Potential, Führen und Managen in der digitalen Transformation (2020) 287–312. doi: 10.1007/978-3-658-28670-5_16.

[2] H. Kauffman, A review of predictive factors of student success in and satisfaction with online learning, Research in Learning Technology 23 (2015). doi: 10.3402/RLT.V23.26507.
[3] M. S. Kerr, K. Rynearson, M. C. Kerr, Student characteristics for online learning success, Internet and Higher Education 9 (2006). doi: 10.1016/J.IHEDUC.2006.03.002.
[4] J. Holzer, M. Lüftenegger, S. Korlat, E. Pelikan, K. Salmela-Aro, C. Spiel, B. Schober, Higher Education in Times of COVID-19: University Students' Basic Need Satisfaction, Self-Regulated Learning, and Well-Being, AERA Open (2021) doi: 10.1177/23328584211003164.
[5] L. Wong, Student Engagement with Online Resources and Its Impact on Learning Outcomes, Journal of Information Technology Education: Innovations in Practice 12 (2013) 129–146. doi: 10.28945/1829.
[6] R. A. Rasheed, A. Kamsin, N. A. Abdullah, Challenges in the online component of blended learning: A systematic review, Computers & Education 144 (2020). doi: 10.1016/J.COMPEDU.2019.103701.
[7] B. J. Zimmerman, Self-Regulated Learning and Academic Achievement: An Overview, Educational Psychologist 25 (1990) 3–17. doi: 10.1207/S15326985EP2501_2.
[8] J. Broadbent, W. L. Poon, Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review, The Internet and Higher Education 27 (2015) 1–13. doi: 10.1016/J.IHEDUC.2015.04.007.
[9] J. Wong, M. Baars, D. Davis, T. van der Zee, G.-J. Houben, F. Paas, Supporting Self-Regulated Learning in Online Learning Environments and MOOCs: A Systematic Review, International Journal of Human-Computer Interaction 35 (2019) 356–373. doi: 10.1080/10447318.2018.1543084.
[10] R. Pérez-Álvarez, J. Maldonado-Mahauad, M. Pérez-Sanagustín, Tools to Support Self-Regulated Learning in Online Environments: Literature Review, Lecture Notes in Computer Science 11082 (2018) 16–30. doi: 10.1007/978-3-319-98572-5_2.
[11] M. Richardson, C. Abraham, R. Bond, Psychological correlates of university students' academic performance: A systematic review and meta-analysis, Psychological Bulletin 138 (2012) 353–387. doi: 10.1037/A0026838.
[12] R. A. Bjork, J. Dunlosky, N. Kornell, Self-Regulated Learning: Beliefs, Techniques, and Illusions, Annual Review of Psychology 64 (2013) 417–444. doi: 10.1146/ANNUREV-PSYCH-113011-143823.
[13] R. Azevedo, A. F. Hadwin, Scaffolding Self-regulated Learning and Metacognition – Implications for the Design of Computer-based Scaffolds, Instructional Science 33 (2005) 367–379. doi: 10.1007/S11251-005-1272-9.
[14] I. Jivet, J. Wong, M. Scheffel, M. Valle Torre, M. Specht, H. Drachsler, Quantum of choice: How learners' feedback monitoring decisions, goals and self-regulated learning skills are related, ACM International Conference Proceeding Series (2021) 416–427. doi: 10.1145/3448139.3448179.
[15] E. Araka, E. Maina, R. Gitonga, R. Oboko, Research trends in measurement and intervention tools for self-regulated learning for e-learning environments—systematic review (2008–2018), Research and Practice in Technology Enhanced Learning 15 (2020) 1-21. doi: 10.1186/S41039-020-00129-5.
[16] R. S. Jansen, A. van Leeuwen, J. Janssen, S. Jak, and L. Kester, Self-regulated learning partially mediates the effect of self-regulated learning interventions on achievement in higher education: A meta-analysis, Educational Research Review 28 (2019). doi: 10.1016/J.EDUREV.2019.100292.
[17] S. A. Karabenick, Seeking help in large college classes: A person-centered approach, Contemporary Educational Psychology 28 (2003). doi: 10.1016/S0361-476X(02)00012-7.
[18] A. M. Ryan, P. R. Pintrich, C. Midgley, Avoiding Seeking Help in the Classroom: Who and Why?, Educational Psychology Review 13 (2001) 93–114. doi: 10.1023/A:1009013420053.

[19] L. Zheng, The effectiveness of self-regulated learning scaffolds on academic performance in computer-based learning environments: a meta-analysis, Asia Pacific Education Review 17 (2016) 187-202. doi: 10.1007/S12564-016-9426-9.
[20] J. Bruso, J. Stefaniak, L. Bol, An examination of personality traits as a predictor of the use of self-regulated learning strategies and considerations for online instruction, Educational Technology Research and Development 68 (2020) 2659–2683. doi: 10.1007/S11423-020-09797-Y.
[21] M. S. Polleys, A Study of Relationships between Self-Regulated Learning, Personality, and Achievement, Annual Meeting of the Mid-South Educational Research Association Report, Chattanooga, TN, 2002.
[22] E. Panadero, A Review of Self-regulated Learning: Six Models and Four Directions for Research, Frontiers in Psychology (2017). doi: 10.3389/FPSYG.2017.00422.
[23] M. Puustinen, L. Pulkkinen, Models of Self-regulated Learning: A review, Scandinavian Journal of Educational Research 45 (2001) 269–286. doi: 10.1080/00313830120074206.
[24] B. J. Zimmerman, A. Bandura, M. Martinez-Pons, Self-Motivation for Academic Attainment: The Role of Self-Efficacy Beliefs and Personal Goal Setting, American Educational Research Journal 29 (1992) 663–676. doi: 10.3102/00028312029003663.
[25] E. A. Locke, K. N. Shaw, L. M. Saari, G. P. Latham, Goal setting and task performance: 1969-1980, Psychological Bulletin 90 (1981)125–152. doi: 10.1037/0033-2909.90.1.125.
[26] E. L. Deci, R. M. Ryan, Self-determination theory, in: P. A. M. Van Lange, A. W. Kruglanski, E. T. Higgins (Eds.), Handbook of Theories of Social Psychology, SAGE Publications Ltd, 2012, pp. 416–437. doi: 10.4135/9781446249215.N21.
[27] J. Reeve, Self-determination theory applied to educational settings, in: E. L. Deci, R. M. Ryan, (Eds), Handbook of Self-Determination Research, University of Rochester Press, 2002, pp. 2–183.
[28] J. Reeve, R. Ryan, E. L. Deci, Jang H, Understanding and promoting autonomous self-regulation: A self-determination theory perspective, in: D. H. Schunk and B. J. Zimmerman (Eds), Motivation and self-regulated learning: Theory, research, and applications, Lawrence Erlbaum Associates Publishers, 2008, pp. 223–244.
[29] E. A. Locke, Toward a theory of task motivation and incentives, Organizational Behavior and Human Performance 3 (1968) 157-189. doi: 10.1016/0030-5073(68)90004-4.
[30] N. Nurjannah, A. Setiawan, D. Rusdiana, M. Muslim, University students' ability in setting own learning goals on heat conductivity concept, Journal of Physics: Conference Series 1521 (2020). doi: 10.1088/1742-6596/1521/2/022049.
[31] K. Beckman, T. Apps, S. Bennett, B. Dalgarno, G. Kennedy, L. Lockyer, Self-regulation in open-ended online assignment tasks: the importance of initial task interpretation and goal setting, Studies in Higher Education 46 (2019) 821–835. doi: 10.1080/03075079.2019.1654450.
[32] G. Oettingen, Future thought and behaviour change, European Review of Social Psychology 23 (2012) 1–63. doi: 10.1080/10463283.2011.643698.
[33] G. Siemens, 1st International Conference on Learning Analytics and Knowledge, 2010. URL: https://tekri.athabascau.ca/analytics/.
[34] P. H. Winne, Construct and consequential validity for learning analytics based on trace data, Computers in Human Behavior 112 (2020). doi: 10.1016/J.CHB.2020.106457.
[35] P. H. Winne, Learning Analytics for Self-Regulated Learning, in: C. Lang, G. Siemens, A. Wise, D. Gašević (Eds), Handbook of Learning Analytics, Society for Learning Analytics Research, 2017, 241–249. doi: 10.18608/HLA17.021.
[36] O. Viberg, M. Khalil, M. Baars, Self-regulated learning and learning analytics in online learning

environments: A review of empirical research, ACM International Conference Proceeding Series (2020) 524–533. doi: 10.1145/3375462.3375483.
[37] J. van der Graaf, I. Molenaar, L. Lim, Y. Fan, K. Engelmann, D. Gašević, M. Bannert, Facilitating self-regulated learning with personalized scaffolds on student's own regulation activities, Companion Proceedings 10th International Conference on Learning Analytics & Knowledge (2020) 46–48.
[38] M. Bannert, I. Molenar, R. Azevedo, S. Järvelä, D. Gašević, Relevance of Learning analytics to measure and support students' learning in adaptive educational technologies, ACM International Conference Proceeding Series (2017) 568–569. doi: 10.1145/3027385.3029463.
[39] M. Rahmani Hanzaki C. Demmans Epp, The Effect of Personality and Course Attributes on Academic Performance in MOOCs, Lecture Notes in Computer Science 11082 (2018) 497–509. doi: 10.1007/978-3-319-98572-5_38.
[40] A. Tlili, F. Essalmi, M. Jemni, Kinshuk, N. S. Chen, Role of personality in computer based learning, Computers in Human Behavior 64 (2016) 805–813. doi: 10.1016/J.CHB.2016.07.043.
[41] G. Wang, Y. Wang, X. Gai, A Meta-Analysis of the Effects of Mental Contrasting With Implementation Intentions on Goal Attainment, Frontiers in Psychology (2021). doi: 10.3389/FPSYG.2021.565202.
[42] I. Dekker, E. M. de Jong, M. C. Schippers, M. de Bruijn-Smolders, A. Alexiou, B. Giesbers, Optimizing students' mental health and academic performance: AI-enhanced life crafting, Frontiers in Psychology 11 (2020). doi: 10.3389/FPSYG.2020.01063.
[43] S. Demetriadis, A. Karakostas, T. Tsiatsos, S. Caballé, Y. Dimitriadis, A. Weinberger, P. M. Papadopoulos, G. Palaigeorgiou, C. Tsimpanis, M. Hodges, Towards Integrating Conversational Agents and Learning Analytics in MOOCs, Lecture Notes on Data Engineering and Communications Technologies 17 (2018) 1061-1072. doi: 10.1007/978-3-319-75928-9_98.
[44] B. Sun, S. Lai, C. Xu, R. Xiao, Y. Wei, Y. Xiao, Differences of online learning behaviors and eye-movement between students having different personality traits, MIE 2017 Proceedings of the 1st ACM SIGCHI International Workshop on Multimodal Interaction for Education (2017) 71–75. doi: 10.1145/3139513.3139527.
[45] G. Sedrakyan, J. Malmberg, K. Verbert, S. Järvelä, P. A. Kirschner, Linking learning behavior analytics and learning science concepts: Designing a learning analytics dashboard for feedback to support learning regulation, Computers in Human Behavior 107 (2020). doi: 10.1016/J.CHB.2018.05.004.
[46] J. Wong, M. Baars, B. B. de Koning, T. van der Zee, D. Davis, M. Khalil, G. J. Houben, F. Paas, Educational Theories and Learning Analytics: From Data to Knowledge, in: D. Ifenthaler, D. K. Mah, J. Y. K. Yau (Eds), Utilizing learning analytics to support study success, Springer, 2018, pp. 3–25. doi: 10.1007/978-3-319-64792-0_1.
[47] D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, T. P. Group, Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement, PLOS Medicine (2009). doi: 10.1371/JOURNAL.PMED.1000097.
[48] T. R. Chidester, W. C. Grigsby, A Meta-Analysis of the Goal Setting-Performance Literature, Academy of Management Proceedings 1984 (2017) 202-206. doi: 10.5465/AMBPP.1984.4978779.
[49] T. Epton, S. Currie, and C. J. Armitage, Unique effects of setting goals on behavior change: Systematic review and meta-analysis, Journal of consulting and clinical psychology (2017) 1182–1198. doi: 10.1037/CCP0000260.
[50] I. Jivet, M. Scheffel, M. Specht, H. Drachsler, License to Evaluate: Preparing Learning Analytics Dashboards for Educational Practice, Proceedings of the 8th International Conference on Learning Analytics and Knowledge (2018). doi: 10.1145/3170358.
[51] L. McCardle, E. A. Webster, A. Haffey, A. F. Hadwin, Examining students' self-set goals for self-regulated learning:

Goal properties and patterns, Studies in
Higher Education 42 (2016) 2153-2169.
doi: 10.1080/03075079.2015.1135117.

Citizen science, data science and education: how to support teacher's inspiration during the learning activities design with technology enhance learning

Miriam Calvera-Isabal, Patricia Santos and Davinia Hernández-Leo

Pompeu Fabra University, Plaça de la Mercè, 10-12 08002, Barcelona, Spain

Abstract

This research will investigate the potential that Citizen Science (CS) projects data has in a formal educational context to learn. CS involves citizens in scientific research generating knowledge and scientific results. Citizens participate in CS projects conducting many activities developing skills, interest in science or scientific literacy. These projects share their information in online repositories also called CS platforms to inform citizens about the aim of the project, their advances on research or how to take part in it. Although the connection between CS and education has been explored, remains to be understood and must be made more explicit. Web scraping and data mining methods have the potential to obtain CS projects data available online and analyze it to extract conclusions. The main aim of this research is to understand how to analyze and visualize CS data in a technology enhanced learning (TEL) tool to support educators during the learning design of educational activities. It is also intended to improve scientific knowledge and to bring official science closer to educational environments.

Keywords [1]

Citizen science, technology enhanced learning, data science, web scraping

1. Introduction

Scientific literacy and critical thinking are important skills for youth to raise awareness and to address today's societal challenges [1]. Citizen science (CS) by involving the general public (from youth to adults) in scientific work, might enhance public understanding of science, contribute to Science, Technology, Engineering and Mathematics (STEM) career motivation and promote values like ecology or respect for the natural environment [2, 3, 4, 5]. Scientific research in CS is organized into projects, in which participants carry out many types of activities, depending on the typology of participation defined [6]. On taking part of the project, citizens might develop: interest in science and the environment, self-efficacy for science and the environment, motivation for science and the environment, knowledge of the nature of science, skills of science inquiry and behavior and stewardship [7].

In order to promote and support CS projects, there are many online platforms that acts as repositories containing information about CS projects and other resources (i.e., EU-Citizen science platform [8]). The platforms share descriptive metadata about the CS project but only some of those follow metadata standards to show it in a structured way [9]. The Project Metadata Model (PMM) which is part of the Public Participation in Scientific Research (PPSR) metadata standard [10] describes project characteristics. Data shared in online platforms has the purpose of explaining to a particular audience what a citizen science

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: miriam.calvera@upf.edu(A.1); patricia.santos@upf.edu (A. 2); davinia.hernandez-leo@mail.com (A. 3)
ORCID: 0000-0003-4117-6953 (A. 1); 0000-0002-7337-2388 (A. 2); 0000-0003-0548-7455 (A. 3)

CEUR Workshop Proceedings (CEUR-WS.org)

project is about. These texts, in general, use special language related to science and contain information about the project aim or an explanation of the research. Web scraping techniques in combination with data mining methods have been used to extract and analyze data from online sites to obtain conclusions in many fields of science [11]. The use of data extracted from texts, that contain information about science, in combination with context of real problems and instructions has the potential of improving scientific literacy [12].

Designing, planning and developing activities requires pedagogical design capacity, design competencies and design expertise of teachers during the learning design process [13]. It is expected that teachers have subject matter knowledge (SMK) and pedagogical content knowledge (PCK) to develop learning designs [14] although it's possible that they need information, materials or training about specific topics. Citizen science projects support participants by developing educational materials (i.e., guides, posters, manuals, videos or podcasts) or sharing results or information about the project that teachers can use to inspire them during the learning design [15, 16]. Our hypothesis is that facilitating data access for educational purposes would have a positive impact on teachers' scientific knowledge and pedagogical skills that would influence on student's scientific literacy and its relation to science [17].

Technology tools that support teachers during the learning designs help them to ensure a better learning experience [18]. Although these tools try to cover teacher's needs like containing relevant resources (i.e Open educational resources (OER) [19] or supporting them during the design of activities, there are barriers or factors that affect the adoption or usage of the tool [20]. The benefits of involving teachers as designers during the design process of technology enhancing learning (TEL) are numerous: from improving student's learning, their own learning about technology or motivation and commitment of using technology and implementing it [21, 22]. The research conducted in this thesis will be considered to (co)design (with educators) and implement a digital tool to inspire and support teachers. Exploring a tool that uses and shows data about CS projects during the learning design process in a formal education context, will derive from improving SMK that will foster on developing PCK.

2. Thesis statement

The aim of this research is to better understand the connections between education and citizen science and to identify the potential that data from CS has to support the design of learning activities. The main research question is: *"How can data science methods be effectively used to gain understanding of the potential that web data about citizen science projects have to inspire teachers in designing for science learning outcomes?".* The related sub research questions are the followings:

- How web scraping and data mining methods can be used to collect/analyze data online about citizen science projects?
- How data from CS projects can be presented/analyzed in relation to their potential to support learning outcomes in formal settings?
- What features and content should be integrated into a digital tool to inspire teachers in the design process of scientific learning activities based on citizen science?

3. Methodology

The methodology selected for this study is Design-Based Research (DBR), it is expected to meet the objective of contributing to understanding the connections between citizen science and educational research. First DBR is applied to analyze the literature exploring the connection between citizen science and education, and identifying gaps. This is an iterative process where the educator's needs will be taken into account involving them in the design process and evaluation of the prototype. The tool will be used in a real educational context to assess whether it meets the teachers' needs and performs the function of supporting teachers during the learning designs. Finally, from the lessons learned, actions and recommendations will be proposed to connect citizen science with education in formal settings.

Mixed methods will be used in an iterative process of testing and refinement cycles of the design process [23, 24]. Both qualitative and quantitative methods will be applied to obtain results for the research questions defined above:

- *Literature review and exploration* to explore previous work done and how data is structured in online platforms
- *Web scraping methods* will be used to extract CS projects metadata, from online platforms using web scraping tools [25]
- *Workshops with key stakeholders* will be conducted to identify citizen science community interest on data and teachers needs during the design of learning activities
- *Data mining Methods for data analysis* will be applied to the data extracted and to explore problems related to the ways of reporting data
- *TEL tool* development

The PPM model from the PPSR metadata standard will be used during this research to structure data extracted in a database. Data mining methods will be applied to analyze the data stored in the database and obtain conclusions about CS and its connection to education.

Moreover, collaborative partnerships with experts will be built, to apply research findings aligned to the teachers' needs, to have a positive effect on teaching and learning [26]. To fulfil the main question and research objectives, many activities have been designed, revised and evaluated during the research. Interviews and workshops with teachers and key users to define and validate data needs, co-design the tool and evaluate and test the final design of the tool will be the main actions developed during the evaluation process.

4. Research plan, possible limitations and risks and progress done so far

Part of the activities defined to achieve research objectives are framed within the CS Track project (European Union's Horizon 2020 research and innovation program under grant agreement No 872522) [27]. The work to be done during the research is divided into four different phases. There are planned activities to address each research objective by applying research methods defined above:

1. Initial phase

- *Literature review* about citizen science, its connection to education, TEL, data science methods, web scraping methods and teacher's learning designs process.
- *Research design and definition*

2. Data extraction

- *Explore and study how citizen science projects information is shared online*. At this stage, there is to explore how citizen science is conducted online and which information about citizen science projects is available
- *Crawling citizen science projects data from online platforms*
- *Defining descriptors/categories to classify the data and analyzing existing data* to detect issues with the data. Analyze metadata standards to be used to store classified data extracted and define characteristics of the central database
- *Applying computational techniques to address the data problem*

3. Data analysis

- *Defining and applying mixed methods to analyze the data*
- *Creating post-processed data datasets of interest to the community*

4. Tool development and validation *(iterative process)*

- *Identifying how teachers design learning activities and their needs* during the process
- *Designing tool functionalities with teachers*
- *Tool development*
- *Evaluating the tool with teachers to validate the design proposed and the usability*. It will also be evaluated if the tool fulfils the objective of inspiring teachers and students

Data extraction and crawler development was done during this first year (Initial phase). An initial version of the database has been created and data has been initially analyzed (data extraction). Some quantitative methods and data mining methods have been applied so far with initial outcomes (data analysis). Hereinafter, data analysis methods will be applied to the data stored (data analysis) and, in parallel, the gathering of key user tool requirements will begin before the end of the second year. The outcomes of data analysis will be available at the middle of third year at the same time the tool will be being developed. Finally for the first quarter of last year the tool will be tested, improved and the potential will be validated by key users (Tool development and validation).

4.1 Identification and prevention of possible limitation and risks

This study will be focused on analyzing science teaching in formal education needs (primary and secondary school levels) and will not take into account other educational levels due to lack of time and resources to cover all. This research will not analyze either the impact on student's learning because of the same limitations. Nevertheless, teacher's will be asked about their experience and perceptions of in which way students have learned after developing activities designed by them. Finally, finding participants to join co-design sessions is challenging so we will do an open call to invite secondary teachers to join the case studies sessions. In addition to this, our research plan includes the organization of workshops with pre-service teachers that are studying a master degree in UPF for teaching science subjects in secondary schools.

4.2 Progress done so far

Being part of the CS Track project, gives us the opportunity to be in touch with the citizen science community and participate in conferences. It was on *"Knowledge for Change: A decade of Citizen Science (2020-2030) in support of the SDGs"* [28], which took place on 14th-15th October 2020 online and in Berlin where we presented our advances on data extraction and its potential on SDG [29]. Furthermore, during the *"CitSciVirtual"* [30] conference which took place online throughout May 2021, we presented a poster about database development [31] and a workshop where we presented metadata stored and got feedback from the community about their data needs.

A preliminary study of how data mining methods allow us to know more about citizen science and its connection with education has been accepted for the CELDA conference [32]. This proof of concept was developed to obtain initial results of the research, design research and select technology will be used.

Regarding workshops with science secondary teachers and tool development (RO3), we have received *"Grant for activities to increase the social impact of research"* from UPF [33] to conduct it during 2021. As planned, it will be done during the last quarter of second year. As part of the CS-Track project, workshops will also be held with key stakeholders (teachers and/or CS participants) Furthermore, as part of *"Makers a les aules (20-21)"* program [34], it has developed the first version of the tool to be tested with students (8 to 10 years old) and primary school teachers (Figure 1). The tool contained information about some citizen science projects related to the subject of the activity (i.e., sea pollution). It allowed teachers and students to read more about the project itself and the tools used by participants.

During the co-design activity with teachers and one of the activities with students, they explored the tool and the information shared about citizen science projects and it was evaluated at the end of the program the influence of this information on the activity designed and results. The influence of citizen science projects data visualization has been analyzed on the subject of *human-machine interaction* with UPF undergraduate students. The tool used by students contained information about citizen science projects and was assigned to a sustainable development goal (SDG). This relation was established because of the issue addressed by the activity. Apart from the description and tools used by participants, information from the web from where the data has been extracted was also added in case students wanted to explore the project in more detail (Figure 2).

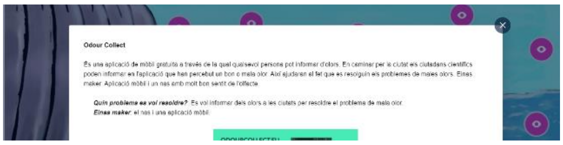

Figure 1: First version of the tool used in *Makers a les aules* (2020-2021) with primary school students and teachers

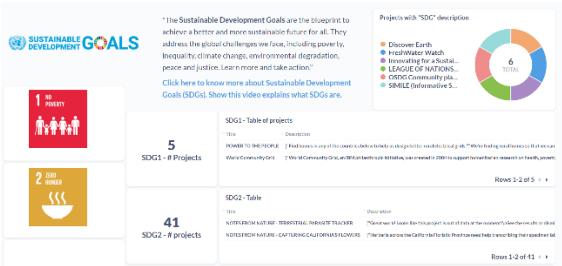

Figure 2: First version of the tool used in *Human-computer interaction* subject with undergraduate students at UPF

5 Expected contributions

The proposed study will make contributions to the TEL and CS fields on the following aspects (Figure 3):

1. *Technical architecture of web scraping tools and data management methods* to analyze and describe how citizen science information is available online. As a result, datasets of citizen science projects will be developed.

2. The study will provide *evidence on how computational data analytics methods can be applied* in the context on citizen science to broaden the knowledge about this field and its relation to education

3. *Proposal and development of a technical environment* to extract and process data and tool to show it addressing the main RQ.

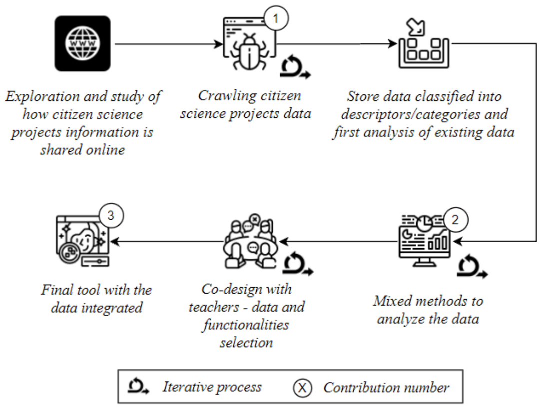

Figure 3: Data flow and expected contributions (identified with the numbers on the list).

This research aims to contribute to TEL and CS fields but mainly tries to impact on teaching/learning science in formal education settings. This study will be focused on analyzing science teaching in formal education needs during the conceptualization phase of the learning design process.

Lessons learned from the data scraping and data mining process connecting CS and Education, will be shared in the form of guidelines, datasets and other contributions. A tool will be co-designed with teachers as an inspirational resource to get inspiration in regards to certain scientific topics, and as a facilitator to help them to design activities about science. Furthermore, it is expected that the data exploration process will potentially improve teachers SMK and PCK.

6 Acknowledgements

This work has been partially funded by the CS Track project, European Union's Horizon 2020 research and innovation program under grant agreement No 872522., a Grant for activities to increase the social impact of research" from UPF, the EU Regional Development Fund and the National Research Agency of the Spanish Ministry of Science and Innovation under project grants TIN2017-85179-C3-3-R, PID2020-112584RB-C33. D. Hernández-Leo (Serra Húnter) acknowledges the support by ICREA under the ICREA Academia program.

7 References

Siarova, H., Sternadel, D. & Szőnyi, E. 2019, Research for CULT Committee – Science and Scientific Literacy as an Educational Challenge, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

[1] Vohland, K., Land-Zandstra, A., Ceccaroni, L., Lemmens, R., Perelló, J., Ponti, M., ... & Wagenknecht, K. (2021). The Science of Citizen Science Evolves. Chapter 1. in Vohland, K. et al (Eds.).(2021) The Science of Citizen Science. Springer. pp 1-12. doi: 10.1007/978-3-030-58278-4.

[2] Strasser, B., Baudry, J., Mahr, D., Sanchez, G., & Tancoigne, E. (2019). " Citizen Science"? Rethinking Science and Public Participation. Science & Technology Studies, 32 (ARTICLE), 52-76.

[3] Hiller, S. E., & Kitsantas, A. (2014). The effect of a horseshoe crab citizen science program on middle school student science

performance and STEM career motivation. School Science and Mathematics, 114(6), 302-311.

[4] Kobori, H., Dickinson, J. L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., ... & Miller-Rushing, A. J. (2016). Citizen science: a new approach to advance ecology, education, and conservation. Ecological research, 31(1), 1-19.

[5] Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Online Submission.

[6] Phillips, T., Porticella, N., Constas, M. and Bonney, R., 2018. A Framework for Articulating and Measuring Individual Learning Outcomes from Participation in Citizen Science. Citizen Science: Theory and Practice, 3(2), p.3. URL: http://doi.org/10.5334/cstp.126

[7] EU-Citizen.Science platform. (2021, July 29). eu-citizen.science. URL: https://eu-citizen.science/ .

Wagenknecht, K., Woods, T., Sanz, F. G., Gold, M., Bowser, A., Rüfenacht, S., ... & Piera, J. (2021). EU-Citizen. Science: A Platform for Mainstreaming Citizen Science and Open Science in Europe. Data Intelligence, 3(1), 136-149.

[8] Citizen Science Association Data & Meta Data Working Group. (2021, July 29). PPSR Core, A Data Standard for Public Participation in Scientific Research (Citizen Science). URL: https://core.citizenscience.org/docs/project .

[9] Thomas, D. M., & Mathur, S. (2019, June). Data analysis by web scraping using python. In 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA) (pp. 450-454). IEEE.

[10] Sørvik, G. O., & Mork, S. M. (2015). Scientific literacy as social practice: Implications for reading and writing in science classrooms. Nordic Studies in Science Education, 11(3), 268-281.

[11] Huizinga, T., Handelzalts, A., Nieveen, N., & Voogt, J. (2015). Fostering teachers' design expertise in teacher design teams: conducive design and support activities. The Curriculum Journal, 26(1), 137-163.

[12] Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. Research in science Education, 38(3), 261-284.

[13] Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience, 59(11), 977-984.

[14] Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. International Journal of Science Education, 27(9), 1099-1121.

[15] Chan, K. K. H., & Yung, B. H. W. (2018). Developing pedagogical content knowledge for teaching a new topic: More than teaching experience and subject matter knowledge. Research in Science Education, 48(2), 233-265.

[16] Bennett, S., Agostinho, S., & Lockyer, L. (2015). Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices. Computers & Education, 81, 211-220.

[17] Hylén, J. (2021). Open educational resources: Opportunities and challenges.

[18] Dagnino, F. M., Dimitriadis, Y. A., Pozzi, F., Asensio-Pérez, J. I., & Rubia-Avi, B. (2018). Exploring teachers' needs and the existing barriers to the adoption of Learning Design methods and tools: A literature survey. British Journal of Educational Technology, 49(6), 998-1013.

[19] Kali, Y., McKenney, S., & Sagy, O. (2015). Teachers as designers of technology enhanced learning. Instructional science, 43(2), 173-179.

[20] Recker, M., Walker, A., Giersch, S., Mao, X., Halioris, S., Palmer, B., ... & Robertshaw, M. B. (2007). A study of teachers' use of online learning resources to design classroom activities. New Review of Hypermedia and Multimedia, 13(2), 117-134.

[21] Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the

research agenda. Educational Technology & Society, 11(4), 29–40.
[22] Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). Sage publications.
[23] Daniel Glez-Peña, Anália Lourenço, Hugo López-Fernández, Miguel Reboiro-Jato, Florentino Fdez-Riverola, Web scraping technologies in an API world, Briefings in Bioinformatics, Volume 15, Issue 5, September 2014, Pages 788–797, URL: https://doi.org/10.1093/bib/bbt026
[24] Getenet, S. (2019). Using design-based research to bring partnership between researchers and practitioners. Educational Research, 61(4), 482-494.
[25] CS Track project. (2021, July 29). CS Track, investigating citizen science. URL: https://cstrack.eu/
[26] Museum für Naturkunde – Leibniz Institute for Evolution and Biodiversity Science. (2021, July 29). Knowledge for Change: Citizen Science SDG Conference. URL: https://www.museumfuernaturkunde.berlin/en/museum/events/knowledge-change-citizen-science-sdg-conference
[27] Patricia Santos, Miriam Calvera, Laia Albó, Julia Lorke, Ulrich Hoppe, & Davinia Hernández-Leo. (2020). CS-Track database: a central database of CS projects in Europe that can be key to understand the connection of CS and SDGs. Presented at the Citizen Science SDG Conference (CS SDG), Zenodo. URL: http://doi.org/10.5281/zenodo.4095157
[28] Citizen Science Association (CSA). (2021, July 29). CitSciVirtual 2021. URL: https://citizenscience.org/home/events/conferences/citscivirtual/
[29] Miriam Calvera-Isabal, Patricia Santos, Ishari Amarasinghe, & Davinia Hernandez-Leo. (2021). A central database of CS projects that can open a new perspective on CS knowledge. Presented at the CitSci virtual (CitSci virtual), Zenodo. URL: http://doi.org/10.5281/zenodo.4773098
[30] 18th International Conference on Cognition and Exploratory Learning in the Digital Age (CELDA 2021). (2021, July 29). CELDA conference 2021. URL: https://www.celda-conf.org/ .
[31] Pompeu Fabra University. (2021, July 29). Grants for activities to increase the social impact of research. URL: https://www.upf.edu/recercaupf/convocatoria-ajuts-impacte-social-recerca
[32] Pompeu Fabra University. (2021, July 29). Makers a les aules: Edició 2020-2021 URL: https://www.upf.edu/es/web/tide/news/-/asset_publisher/JP7iPN458OrU/content/id/244364382/maximized#.YPaDbuj7RPY

Design and implementation of accessible open-source augmented reality learning authoring tool

Deogratias Shidende[a,b]

[a] University of Hohenheim, Schloss Hohenheim 1, 70599 Stuttgart, Germany
[b] Duale Hochschule Baden-Württemberg (DHBW) Heidenheim, Marienstraße 20, 89518 Heidenheim, Germany

Abstract

The emerging learning technologies have brought new dimensions to the learning process. Particularly in this era, where due to health reasons, online learning is preferred, augmenting reality with digital information is paramount. Unfortunately, most of the existing augmented reality learning applications were not designed for different abilities, apart from having substantial annual licenses. Further, they require advanced digital competence such as programming, which many non-technical educational practitioners lack. This research attempts to fill this gap by designing and implementing an accessible open-source augmented reality learning authoring tool that will empower non-technical educational practitioners of different abilities to develop and use augmented reality applications for teaching and learning purposes.

Keywords [1]

Learning Technologies, Augmented Reality, Augmented Reality Learning, Accessibility, Open-source

1. Introduction

Augmented Reality (AR) is a technology that superimposes real-world objects with virtual generated information in the same space, thus providing a more useful composite view. While AR is widely used with the sense of sight, it also applies to smell, touch, and hearing senses [1].

Since its inception, AR has been used in a wide range of applications, including entertainment, mapping, transportation, health, and education sectors. At first, AR was introduced as a training tool for airline and Air Force pilots during the 1960s [2]. Due to the advancement in information technology, AR is currently implemented in computer and mobile devices without requiring expensive technology such as head-mounted displays [3]. For learning purposes, AR creates immersive hybrid learning environments that facilitate critical thinking, problem-solving, and communicating through interdependent collaborative exercises [4–6]. Other studies by Akçayır *et al.* [7] and Mylonas *et al.* [8] revealed that AR improves university students' laboratory skills and helps them build positive attitudes. A variety of research projects examined the initial suitability of AR for different learning scenarios, e.g. flipped learning or experiential learning, and in various disciplines [9–12] as well as its integration in teaching and learning processes [13].

However, studies show that most AR applications have been developed using proprietary Software Development Kit (SDK) such as Vuforia, Kudan AR, Adobe Aero, and Wikitude [5]. These are potent tools for handling all three AR system stages, namely recognition, tracking, and mixing, allowing ease of development for the developers [14], [15]. However, these AR tools are not open-source, and they carry heavy, substantial annual license fees. This represents an obstacle for

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: deogratias.shidende@dhbw-heidenheim.de (Deogratias Shidende)
ORCID: 0000-0002-2181-958X (Deogratias Shidende)

many small to mid-sized companies as well as institutions of higher education alike.

In fact, open-source software does not only refer to the availability of source code. Moreover, it designates a broader sense of values that embraces and celebrates open exchange principles, collaborative participation, rapid prototyping, transparency, meritocracy, and community-oriented development [16, 17]. By developing an open-source tool, programmers and software users benefit from the control over the tool, training from the communities behind it, security, and stability. Thus, an open-source AR tool will benefit from using existing parts of an open-source learning tool and enhance it for AR authoring. Therefore, it provides an authoring tool available with an open-source license for use and opens for further future development by business partners and other stakeholders.

Research further reveals that few AR applications have been developed by using an open-source library such as ARToolkit, AR.js and DroidAR. With these libraries, programmers are using traditional languages such as c#, c/c++, python, Java and JavaScript to develop AR applications [5, 14]. This means, developing AR applications requires technical knowledge in these programming languages or hiring computer programmers. Unfortunately, many non-technical instructors lack this digital competence [18–20]. Also, it is costly to hire a programmer for mid-sized companies and educational institutions [21]. Furthermore, most of these applications are challenged with usability problems, inadequate technology experience, interface design errors, and technical difficulties [3, 22–24].

World Health Organisation estimates about 15% of the world's population have at least one particular form of disability. This number increases due to increased chronic diseases, ageing, and technology discovery to identify various disabilities [25]. The various forms of disabilities include auditory, cognitive, learning and neurological, physical, speech and visual disabilities. These forms require different approaches and strategies to reduce the obstacles in accessing the AR applications [26]. Most existing AR Learning applications, however, target one form of disability. For example, a multi-sensory AR map targets blind and low vision students [27], whereas MoviLetrando targets Autism Spectrum Disorder students [28]. Other authors dealt with the auditory ability [29], low vision [30] and cognitive support [31]. Unfortunately, research shows that many proprietary and open-source AR applications are not designed for users with different abilities [32–34] and exclude many people who would benefit from these applications.

This research, therefore, aims to use existing open-source libraries and approaches to design and implement an inclusive and accessible AR tool based on an open-source learning environment, such as Moodle. It can be used to author AR learning in different disciplines by users with varying levels of accessibility and in different learning settings, from university classrooms and for on-the-job training.

2. Research objectives and questions

The main objective is to develop an accessible augmented reality learning authoring tool. Specifically, the research aims the following

1. To identify the requirements for developing an open-source AR learning authoring tool
2. To develop an open-source tool for authoring AR learning, building on an existing OS learning platform.
3. To validate the AR authoring tool through authoring a pilot AR learning application

This thesis intends to answer the following main question: How can you design and implement an augmented reality learning authoring tool for a broad audience? The secondary research questions are as follows: -

1. What are the requirements for developing an accessible open-source AR learning authoring tool?
2. How can we develop an accessible open-source augmented reality learning authoring tool?
3. What kind of AR learning applications can be authored with the tool?

3. Theoretical framework

The combination of real-world with multimedia elements is one of the promising technologies in the field of education. This follows from the cognitive theory of multimedia learning, which states that people learn better when the instruction is given using both words and pictures than words alone [35]. Further, Buchem et al. [36] argue that AR is characterised by various affordances such as embodied, collaborative, and augmentative affordances. These affordances make AR indispensable in a learning environment as it forages helpful information for learners and constructs more profound knowledge.

Though Garzón noted that the effectiveness of AR in learning is medium [33], numerous studies have reported the interaction between learner and AR artefacts is potent in learning. For instance, AR learning has resulted in learning gain and motivation [3, 32, 37, 38], content understanding and retention [32, 39–41], increased interaction and attention [42, 43], learning efficiency and performance [44, 45] and enhances problem-solving abilities and influence decision making [3, 5].

Various other examples have proved that AR is beneficial in teaching and learning. For instance, Mylonas et al. [8] used AR as a visual aid to teach students how electrical devices consume energy. Fidan and Tuncel [46] integrated AR application with problem-based learning activities to help students understood physics concepts and improve their attitudes towards physics.

Like any other technology, AR is not without challenges and limitations. Alalwan et al. [47] conducted a semi-structured interview with 29 science teachers in a developing country. They found that teachers' competency, proper instructional design and resources were common limitations in AR utilisation. Also, Pellas *et al*. [48] pointed out that teachers could not modify or add content to AR applications. These teachers' incapability might be because most non-technical teachers are at the basic-level of digital competence [49, 50]. Dirin & Laine [51] found usability problems, when evaluated two mobile AR applications. The usability problems in AR are also reported by other researchers [3, 23, 24]. While the usability problems can be solved through following good design principles, Buchem et al [36] proposes interdisciplinary training to alleviate digital illiteracy among educational practioners.

Accessibility is a concept that ensures a product or service is usable by people with different abilities. Designing for accessibility widens a pool of users, opens equal opportunity for various user types and increases the compatibilities with other devices [52, 53]. Accessibility is more than technical standards, it is also a moral obligation and legal requirement. For instance, European Union directives 2016/2102 directs websites and mobile applications of the public sector to be accessible [54].

Despite its significance, many AR applications do not consider accessibility in the early design stage, or they are dealing with one form of ability. Examples of AR studies with a particular ability are numerous. Mentioning a few are Albouys-Perrois *et al*. [27] implemented a Multi-sensory AR map for blind and low vision students by using text-to-speech, tactile tools, and visual calibrated projector. Antão et al [28] improved the performance and reaction time skills of Autism Spectrum Disorder students using the AR computer game MoviLetrando. In auditory ability, Al-Megren & Almutairi [55] developed a mobile application that uses AR to support literacy among hard of hearing children. Another study employed AR to give cognitive support during assembly tasks [31]. Further, a systematic review by Garzón [33] of 61 selected AR in education settings articles from 2012-2018 revealed that only one paper dealt with the accessibility of AR learning. This finding agreed with previous studies by [32] and [34], whose results showed very few systems designed for users with diverse needs.

However, designing for accessibility is more than considering a particular form of disability; it is adhering to accessibility guidelines and standards such as Web Content Accessibility Guidelines (WCAG 2.1) [56] and IEEE Standard for Augmented Reality Learning Experience Model [57]. In addition, consider XR Accessibility User Requirements [58] and follow developers' guidelines such as the XR Association Developer guide [59], helpful in making an XR application accessible. Thus, the development of an accessible AR authoring tool intends to comply with the mentioned standards, guidelines, and use cases, particularly level AA of WCAG 2.1.

Open-source is both a legal term and a development model [60]. Legally, it is governed by an open-source license, a license that is approved by Open Source Initiative (OSI). This license gives the software users the legal power of using, inspecting, modifying and distributing the software source code. These rights are outlined in the ten characteristics of the Open-Source Definition (OSD) [60, 61].

Whether the open-source software will be free of charge or not will depend on the adopted business model and the open-source license used [62].

As a development model, Open-source can be developed in a distributed manner with developers scattered geographically and organisationally [63]. This peer-reviewed manner of development can foster different organisations, such as Universities and companies, to cooperate in producing reliable, cheaper, and faster-delivery software [64]. AlMarzouq et al. [60] argued that the quality of open-source software depends on license, community, and development process. The license, for instance, decides which components to use and encourages or discourages community participation. While the motivated community is essential, the development process determines feedback speed and the review process. Thus, this study intends to adopt an Open-Source license that will enable partner universities and companies to participate in the development of accessible AR learning tool.

4. Research methods

This research aims to design and implement an accessible open-source augmented reality learning authoring tool for non-technical instructors with different levels of abilities. The guiding research methods will be Design-based Research (DBR) blended with Agile Methodology in Scrumban (AMS). While various researchers have successfully used DBR to develop learning interventions [65–67], AMS is an effective project management methodology in information systems development [65]. Both DBR and AMS are iterative and involve practitioners from the early stages of problem analysis to product acceptance. Despite its success, some studies have reported the challenges of DBR. These include researchers' biases [66, 67], the possibility of iterations to exceed available resources [66], and the inapplicability of interventions in different settings [68]. AMS, on another side, has been reported to have a positive influence in both project management knowledge areas and project management triple constraints, i.e. scope, cost and time [69]. Unfortunately, applying AMS to create an intervention without creating knowledge is not research [70, 71]. Thus, we anticipate that AMS and designed research to develop an intervention can complement each other. Some studies that have hybridised the DBR with agility include Cochrane [72], Cooney [73] and Dass [74].

The research will be carried out in higher learning institutions and partner companies located in Germany and Tanzania. The partner universities and companies will provide both educational practitioners and customers. Like other DBR approaches, we will follow a pragmatic paradigm by using appropriate qualitative and quantitative methods [67, 75] such as surveys, interviews, focus groups, and document reviews.

Further, we will follow the DBR processes as outlined by Plomp [70]. Plomp examined various researches conducted by using DBR and concluded the following three phases. The first phase is preliminary research comprising practical problem analysis, literature review and conceptual or theoretical framework development. The second is the development phase, in which the prototype is iteratively developed as a micro-cycle of the research with formative evaluations. And the last is the assessment phase consisting of summative evaluation to check if the intervention meets the agreed specifications [70, 76]. These three phases are conducted iteratively [71, 77].

The AMS consists of roles, processes and artefacts. The roles are scrum master and scrum team. The activities in the process include kickoff, the meeting to plan the sprint, sprint execution, the daily Scrum and the sprint review meeting. The iteration, also known as a sprint, should be planned such that it is completed in a short time. The last component of AMS is scrum artefacts: these are product backlog, sprint backlog, and burnout charts [65]. Thus, since AMS focus on sprints with small deliverables and direct communication among the partners, it can help adapt quickly to the project unpredictability and become helpful to DBR, as shown by Kastl and Romeike [78] and Confrey [79]. They applied the agile methodology to improve intra-communication, team member cooperation and active participation in the DBR design activities.

5. Current status and future work

This work started in January 2021, and it is currently in the completion of the first phase of DBR, specifically, literature review and framework development.

The next steps to accomplish this work are as follows: - To start the data collection and prototype development, employing AMS in prototype development and conducting the summative evaluation. This will be followed by phase three, which is a summative evaluation of the work. We expect to do two to three iterations of this phase model in the next twelve months.

6. Expected contributions

This research will contribute to the empirical knowledge concerning accessible open-source AR learning. Primarily, it will add knowledge on the usage of open-source libraries and approaches in developing an authoring tool for an AR learning tool. The knowledge will be helpful to researchers, academicians, and other enthusiasts to expand the research and extend the work for different educational and societal needs.

It will provide source code for the accessible environment to create AR resources and thus, contribute an interface for non-technical authors to develop AR learning applications suitable for teaching at universities and on-the-job training. We believe students and teachers will achieve their curricula demands through these AR Learning applications.

7. Acknowledgements

This research work is funded by Baden-Württemberg Cooperative State University (DHBW) through the Innovationsprogramm Forschung (IPF). Specifically, the special thanks go to DHBW Heidenheim, which are hosting the AuReLiA - Augmented Reality Learning and Accessibility research laboratory, the partner company Graustich and the partner university Nelson Mandela African Institution of Science and Technology (NM-AIST) Arusha. The views expressed in this document are authors'; hence the DHBW, NM-AIST and Graustich are not responsible for any information it may contain.

8. References

[1] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, ‘Recent advances in augmented reality’, IEEE Comput. Graph. Appl., vol. 21, no. 6, pp. 34–47, 2001.

[2] T. Furness, ‘Helmet-mounted displays and their aerospace applications’, in National Aerospace Electronics Conference, 1969, vol. 1.

[3] M. Akçayır and G. Akçayır, ‘Advantages and challenges associated with augmented reality for education: A systematic review of the literature’, Educ. Res. Rev., vol. 20, pp. 1–11, 2017.

[4] M. Dunleavy, C. Dede, and R. Mitchell, ‘Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning’, J. Sci. Educ. Technol., vol. 18, no. 1, pp. 7–22, 2009.

[5] M.-B. Ibáñez and C. Delgado-Kloos, ‘Augmented reality for STEM learning: A systematic review’, Comput. Educ., vol. 123, pp. 109–123, 2018.

[6] L. López-Faican and J. Jaen, ‘EmoFindAR: Evaluation of a mobile multiplayer augmented reality game for primary school children’, Comput. Educ., vol. 149, p. 103814, 2020, doi: 10.1016/j.compedu.2020.103814.

[7] M. Akçayır, G. Akçayır, H. M. Pektaş, and M. A. Ocak, ‘Augmented reality in science laboratories: The effects of augmented reality on university students’ laboratory skills and attitudes toward science laboratories’, Comput. Hum. Behav., vol. 57, pp. 334–342, 2016.

[8] G. Mylonas, C. Triantafyllis, and D. Amaxilatis, ‘An Augmented Reality Prototype for supporting IoT-based Educational Activities for Energy-efficient School Buildings’, Electron. Notes Theor. Comput. Sci., vol. 343, pp. 89–101, 2019, doi: 10.1016/j.entcs.2019.04.012.

[9] S.-C. Chang and G.-J. Hwang, ‘Impacts of an augmented reality-based flipped learning guiding approach on students’ scientific project performance and perceptions’, Comput. Educ., vol. 125, pp. 226–239, 2018.

[10] J. A. Frank and V. Kapila, ‘Mixed-reality learning environments: Integrating mobile interfaces with laboratory test-beds’, Comput. Educ., vol. 110, pp. 88–104, 2017.

[11] T.-C. Huang, C.-C. Chen, and Y.-W. Chou, ‘Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment’, Comput. Educ., vol. 96, pp. 72–82, 2016.

[12] R. Layona, B. Yulianto, and Y. Tunardi, ‘Web based augmented reality for human body anatomy learning’, Procedia Comput. Sci., vol. 135, pp. 457–464, 2018.

[13] D. Sampaio and P. Almeida, ‘Pedagogical strategies for the integration of Augmented Reality in ICT teaching and learning processes’, Procedia Comput. Sci., vol. 100, pp. 894–899, 2016.

[14] D. Amin and S. Govilkar, ‘Comparative study of augmented reality SDKs’, Int. J. Comput. Sci. Appl., vol. 5, no. 1, pp. 11–26, 2015.

[15] A. Hanafi, L. Elaachak, and M. Bouhorma, ‘A comparative Study of Augmented Reality SDKs to Develop an Educational Application in Chemical Field’, in Proceedings of the 2nd International Conference on Networking, Information Systems & Security, New York, NY, USA, 2019, pp. 1–8. doi: 10.1145/3320326.3320386.

[16] F. Joseph, F. Brian, and S. Raymond Eric, ‘Understanding open source software development’. Addison Wesley, Pearson Education Book, 2001.

[17] opensource.com, ‘What is open source?’ https://opensource.com/resources/what-open-source.

[18] R. Colpani and M. R. P. Homem, ‘An innovative augmented reality educational framework with gamification to assist the learning process of children with intellectual disabilities’, in 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA), 2015, pp. 1–6. doi: 10.1109/IISA.2015.7387964.

[19] J. B. Osuna, J. Gutiérrez-Castillo, M. Llorente-Cejudo, and R. V. Ortiz, ‘Difficulties in the incorporation of augmented reality in university education: Visions from the experts’, J. New Approaches Educ. Res. NAER J., vol. 8, no. 2, pp. 126–141, 2019.

[20] S. Tzima, G. Styliaras, and A. Bassounas, ‘Augmented Reality Applications in Education: Teachers Point of View’, Educ. Sci., vol. 9, no. 2, Art. no. 2, 2019, doi: 10.3390/educsci9020099.

[21] C. Lytridis and A. Tsinakos, ‘Evaluation of the ARTutor augmented reality educational platform in tertiary education’, Smart Learn. Environ., vol. 5, no. 1, pp. 1–15, 2018.

[22] K.-E. Chang, C.-T. Chang, H.-T. Hou, Y.-T. Sung, H.-L. Chao, and C.-M. Lee, ‘Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum’, Comput. Educ., vol. 71, pp. 185–197, 2014.

[23] N. Gavish et al., ‘Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks’, Interact. Learn. Environ., vol. 23, no. 6, pp. 778–798, 2015.

[24] B. S. Hantono, L. E. Nugroho, and P. I. Santosa, ‘Meta-Review of Augmented Reality in Education’, in 2018 10th International Conference on Information Technology and Electrical Engineering (ICITEE), 2018, pp. 312–315. doi: 10.1109/ICITEED.2018.8534888.

[25] World Health Organisation, ‘World Report on Disability’, World Health Organisation, Malta, 2011. [Online]. URL: https://www.who.int/disabilities/world_report/2011/report.pdf

[26] A. Tesolin and A. Tsinakos, ‘Opening Real Doors: Strategies for Using Mobile Augmented Reality to Create Inclusive Distance Education for Learners with Different-Abilities’, in Mobile and Ubiquitous Learning: An International Handbook, S. Yu, M. Ally, and A. Tsinakos, Eds. Singapore: Springer, 2018, pp. 59–80. doi: 10.1007/978-981-10-6144-8_4.

[27] J. Albouys-Perrois, J. Laviole, C. Briant, and A. M. Brock, ‘Towards a Multisensory Augmented Reality Map for Blind and Low Vision People: a Participatory Design Approach’, in Proceedings of the 2018 CHI Conference on Human Factors in Computing

Systems, New York, NY, USA, 2018, pp. 1–14. doi: 10.1145/3173574.3174203.
[28] J. Y. F. de L. Antão et al., ‘Use of Augmented Reality with a Motion-Controlled Game Utilizing Alphabet Letters and Numbers to Improve Performance and Reaction Time Skills for People with Autism Spectrum Disorder’, Cyberpsychology Behav. Soc. Netw., vol. 23, no. 1, pp. 16–22, 2020, doi: 10.1089/cyber.2019.0103.
[29] A. Almutairi and S. Al-Megren, ‘Preliminary investigations on augmented reality for the literacy development of deaf children’, in International Visual Informatics Conference, 2017, pp. 412–422.
[30] J. Herskovitz et al., ‘Making Mobile Augmented Reality Applications Accessible’, 22nd Int. ACM SIGACCESS Conf. Comput. Access., pp. 1–14, 2020, doi: 10.1145/3373625.3417006.
[31] P. Vanneste, Y. Huang, J. Y. Park, F. Cornillie, B. Decloedt, and W. Van den Noortgate, ‘Cognitive support for assembly operations by means of augmented reality: an exploratory study’, Int. J. Hum.-Comput. Stud., vol. 143, p. 102480, 2020, doi: 10.1016/j.ijhcs.2020.102480.
[32] J. L. Bacca Acosta, S. M. Baldiris Navarro, R. Fabregat Gesa, and S. Graf, ‘Augmented reality trends in education: a systematic review of research and applications’, J. Educ. Technol. Soc. 2014 Vol 17 Núm 4 P 133-149, 2014.
[33] J. Garzón, J. Pavón, and S. Baldiris, ‘Systematic review and meta-analysis of augmented reality in educational settings’, Virtual Real., vol. 23, no. 4, pp. 447–459, 2019, doi: 10.1007/s10055-019-00379-9.
[34] H.-K. Wu, S. W.-Y. Lee, H.-Y. Chang, and J.-C. Liang, ‘Current status, opportunities and challenges of augmented reality in education’, Comput. Educ., vol. 62, pp. 41–49, 2013.
[35] R. E. Mayer, The Cambridge handbook of multimedia learning. Cambridge university press, 2005.
[36] I. Buchem, R. Klamma, and F. Wild, ‘Introduction to Wearable Enhanced Learning (WELL): Trends, Opportunities, and Challenges’, in Perspectives on Wearable Enhanced Learning (WELL): Current Trends, Research, and Practice, I. Buchem, R. Klamma, and F. Wild, Eds. Cham: Springer International Publishing, 2019, pp. 3–32. doi: 10.1007/978-3-319-64301-4_1.
[37] I. Radu, ‘Why should my students use AR? A comparative review of the educational impacts of augmented-reality’, in 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2012, pp. 313–314.
[38] J. Buchner and J. Zumbach, ‘Promoting Intrinsic Motivation with a Mobile Augmented Reality Learning Environment.’, Int. Assoc. Dev. Inf. Soc., 2018.
[39] A. M. Kamarainen et al., ‘EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips’, Comput. Educ., vol. 68, pp. 545–556, 2013.
[40] I. Radu, ‘Augmented reality in education: a meta-review and cross-media analysis’, Pers. Ubiquitous Comput., vol. 18, no. 6, pp. 1533–1543, 2014.
[41] M. H. Kurniawan and G. Witjaksono, ‘Human anatomy learning systems using augmented reality on mobile application’, Procedia Comput. Sci., vol. 135, pp. 80–88, 2018.
[42] T. H. Chiang, S. J. Yang, and G.-J. Hwang, ‘Students’ online interactive patterns in augmented reality-based inquiry activities’, Comput. Educ., vol. 78, pp. 97–108, 2014.
[43] M. C. Costa, J. M. Patricio, J. A. Carrança, and B. Farropo, ‘Augmented reality technologies to promote STEM learning’, in 2018 13th Iberian Conference on Information Systems and Technologies (CISTI), 2018, pp. 1–4.
[44] E. Liu, Y. Li, S. Cai, and X. Li, ‘The effect of augmented reality in solid geometry class on students’ learning performance and attitudes’, in International Conference on Remote Engineering and Virtual Instrumentation, 2018, pp. 549–558.
[45] S. Radosavljevic, V. Radosavljevic, and B. Grgurovic, ‘The potential of implementing augmented reality into vocational higher education through mobile learning’, Interact. Learn.

Environ., vol. 28, no. 4, pp. 404–418, 2020.

[46] M. Fidan and M. Tuncel, 'Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education', Comput. Educ., vol. 142, p. 103635, 2019.

[47] N. Alalwan, L. Cheng, H. Al-Samarraie, R. Yousef, A. Ibrahim Alzahrani, and S. M. Sarsam, 'Challenges and Prospects of Virtual Reality and Augmented Reality Utilization among Primary School Teachers: A Developing Country Perspective', Stud. Educ. Eval., vol. 66, p. 100876, 2020, doi: 10.1016/j.stueduc.2020.100876.

[48] N. Pellas, P. Fotaris, I. Kazanidis, and D. Wells, 'Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning', Virtual Real., vol. 23, no. 4, pp. 329–346, 2019, doi: 10.1007/s10055-018-0347-2.

[49] OECD, 'TALIS 2018 Results (Volume I): Teachers and School Leaders as Lifelong Learners'. OECD Publishing, Paris, 2019. [Online]. URL: https://www.oecd-ilibrary.org/content/publication/1d0bc92a-en

[50] F. Caena and C. Redecker, 'Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (Digcompedu)', Eur. J. Educ., vol. 54, no. 3, pp. 356–369, 2019.

[51] A. Dirin and T. H. Laine, 'User Experience in Mobile Augmented Reality: Emotions, Challenges, Opportunities and Best Practices', Computers, vol. 7, no. 2, Art. no. 2, Jun. 2018, doi: 10.3390/computers7020033.

[52] P. Acosta-Vargas, L. Antonio Salvador-Ullauri, and S. Luján-Mora, 'A Heuristic Method to Evaluate Web Accessibility for Users With Low Vision', IEEE Access, vol. 7, pp. 125634–125648, 2019, doi: 10.1109/ACCESS.2019.2939068.

[53] S. Kurt, 'Moving toward a universally accessible web: Web accessibility and education', Assist. Technol., vol. 31, no. 4, pp. 199–208, 2019, doi: 10.1080/10400435.2017.1414086.

[54] E. Lex, 'Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies', Off. J., pp. 1–15, 2016.

[55] S. Al-Megren and A. Almutairi, 'User requirement analysis of a mobile augmented reality application to support literacy development amongst children with hearing impairments', J. Inf. Commun. Technol., vol. 18, no. 2, pp. 207–231, 2019.

[56] W3C Web Accessibility Initiative (WAI), 'Web Content Accessibility Guidelines (WCAG) Overview', Web Accessibility Initiative (WAI), 2018. https://www.w3.org/WAI/standards-guidelines/wcag/.

[57] F. Wild, C. Perey, B. Hensen, and R. Klamma, 'IEEE Standard for Augmented Reality Learning Experience Models', in 2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), 2020, pp. 1–3.

[58] W3C Web Accessibility Initiative (WAI), 'XR Accessibility User Requirements', 2021. https://www.w3.org/TR/xaur/.

[59] XR Association, 'XR ASSOCIATION DEVELOPERS GUIDE', XR Association, 2020.

[60] M. AlMarzouq, L. Zheng, G. Rong, and V. Grover, 'Open source: Concepts, benefits, and challenges', Commun. Assoc. Inf. Syst., vol. 16, no. 1, p. 37, 2005.

[61] Open Source Initiative, 'The Open Source Definition | Open Source Initiative', 2007. https://opensource.org/docs/definition.html.

[62] M. Heron, V. L. Hanson, and I. Ricketts, 'Open source and accessibility: advantages and limitations', J. Interact. Sci., vol. 1, no. 1, pp. 1–10, 2013.

[63] K. Crowston, K. Wei, J. Howison, and A. Wiggins, 'Free/Libre open-source software development: What we know and what we do not know', ACM Comput. Surv. CSUR, vol. 44, no. 2, pp. 1–35, 2008.

[64] J. DJurković, V. Vuković, and L. Raković, 'Open Source Approach in Software Development—Advantages and

Disadvantages', Manag Inforation Syst, vol. 3, pp. 029–033, 2008.
[65] H. F. Cervone, 'Understanding agile project management methods using Scrum', OCLC Syst. Serv. Int. Digit. Libr. Perspect., vol. 27, no. 1, pp. 18–22, 2011, doi: 10.1108/10650751111106528.
[66] T. Anderson and J. Shattuck, 'Design-Based Research: A Decade of Progress in Education Research?', Educ. Res., vol. 41, no. 1, pp. 16–25, 2012, doi: 10.3102/0013189X11428813.
[67] S. Barab and K. Squire, 'Design-Based Research: Putting a Stake in the Ground', J. Learn. Sci., vol. 13, no. 1, pp. 1–14, Jan. 2004, doi: 10.1207/s15327809jls1301_1.
[68] Design-Based Research Collective, 'Design-based research: An emerging paradigm for educational inquiry', Educ. Res., vol. 32, no. 1, pp. 5–8, 2003.
[69] F. Hayat, A. U. Rehman, K. S. Arif, K. Wahab, and M. Abbas, 'The Influence of Agile Methodology (Scrum) on Software Project Management', in 2019 20th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), Jul. 2019, pp. 145–149. doi: 10.1109/SNPD.2019.8935813.
[70] T. Plomp, 'Educational design research: An introduction', Educ. Des. Res., pp. 11–50, 2013.
[71] T. REEVES, 'Design research from a technology perspective', in Educational Design Research, Routledge, 2006.
[72] T. Cochrane, 'hybrid Design based research for Agile Software development (hDAS) in ISD contexts: a discovery from studying how to design MUVEs for VET', in 6th International Conference on Higher Education Advances (HEAd'20), 2020, no. 30-05–2020, pp. 875–882.
[73] L. Cooney and A. Little, 'Implementation of Agile Methods within Instructional Systems Design: A Case Study, 12', 2015.
[74] D. S. Dass and V. Cid, 'An Agile ISD Process to Develop a Medical Simulation, 10', 2018.
[75] F. Wang and M. J. Hannafin, 'Design-based research and technology-enhanced learning environments', Educ. Technol. Res. Dev., vol. 53, no. 4, pp. 5–23, 2005, doi: 10.1007/BF02504682.
[76] A. H. Alghamdi and L. Li, 'Adapting design-based research as a research methodology in educational settings', Int. J. Educ. Res., vol. 1, no. 10, pp. 1–12, 2013.
[77] Y. Ma and S. W. Harmon, 'A Case Study of Design-Based Research for Creating a Vision Prototype of a Technology-Based Innovative Learning Environment', J. Interact. Learn. Res., vol. 20, no. 1, pp. 75–93, 2009.
[78] P. Kastl and R. Romeike, 'Towards agile practices in CS secondary education with a design based research approach', in Proceedings of the 9th Workshop in Primary and Secondary Computing Education, New York, NY, USA, 2014, pp. 130–131. doi: 10.1145/2670757.2670776.
[79] J. Confrey, 'Leading a Design-Based Research Team Using Agile Methodologies to Build Learner-Centered Software', in Designing, Conducting, and Publishing Quality Research in Mathematics Education, K. R. Leatham, Ed. Cham: Springer International Publishing, 2019, pp. 123–142. doi: 10.1007/978-3-030-23505-5_9.

Where change begins: Teacher-students' professional development during internships in media and computer science education

Judit Martínez-Moreno[a,b]

[a] Zurich University of Teacher Education, Lagerstrasse 2, 8090 Zurich, Switzerland
[b] University of Zurich, Institute of Education, Kantonsschulstrasse 3, 8001 Zurich, Switzerland

Abstract
New curricula are being introduced to foster the integration of media and computer science in education. Therefore, it is of high importance to understand how to train teachers to adapt their teaching practices to these new curricula. In this direction, three models are of high importance: COACTIV, TPACK, and the SQD Model. The COACTIV model gives insights into the competences that teachers need to acquire to teach effectively. The TPACK model poses the types of knowledge needed to teach effectively with technology. The SQD Model presents the key strategies to teach teacher-students on the effective integration of technology. However, these models still present some limitations. First, the expression of TPACK in action and the relevance of its components is not clear. Second, the transversal development of these models has not been sufficiently studied. And third, the relationship between these three models is also under-researched. The present doctorate will address these three limitations by studying the professional development of primary education teacher-students during internships in media and computer science. Three main aspects will be analysed: teacher-student-related variables, internship projects, and training settings. A mixed-method approach will be followed, embracing content and thematic analysis, as well as correlation and predictive analysis.

Keywords[1]
Teacher education, teacher-students, internships, media and computer science education, TPACK, COACTIV, SQD Model

1. Introduction

Specific educational frameworks have been developed to collect the competencies and skills that children need to learn to succeed in the 21st century [1, 2]. In Switzerland, the new Curriculum 21 has been introduced in the German-speaking cantons to foster the development of these competences, including a media and computer science module to be taught in elementary education. However, introducing new curricula is not enough. Teachers should be prepared to adapt their teaching practices to provide students with the best opportunities to acquire the competencies needed and set by the curriculum. To do so, it is of high importance to offer teacher training opportunities that aim at acquiring the required knowledge and competencies.[2]

1.1. Teacher competence

Teacher competence is a difficult topic to treat since it is challenging to define what competences are, as well as to identify the competences that teachers have and need to develop, to successfully perform their practice.

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: judit.martinezmoreno@phzh.ch
ORCID: 0000-0001-9234-8220

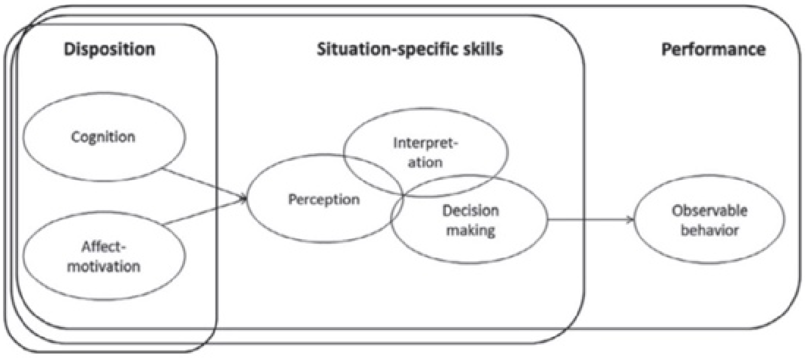

Figure 1: Competence as a continuum taken from Blömeke et al. [3]

After analysing several conceptual frameworks and definitions of "competence" in higher education, the "Competence as a continuum model" was developed [3] (see Figure 1). This model is constituted of 3 parts: the left side includes cognitive, affective, and motivational competences for specific contexts; the right side is the behaviour that can be observed; and this is mediated by the part in the middle, which includes the processes done by the actor, such as perception, interpretation, and decision-making processes.

In the field of teaching, one model that systematically identifies the competencies that teachers need to have to perform a good professional practice is the COACTIV (or *Co*gnitive *Activ*ation in the Classroom) model of teachers' professional competence [4] (see Figure 2, which presents the COACTIV model specified for the context of mathematics teaching). From this perspective, professional teaching practice is an interplay between cognitive and motivational/self-regulatory characteristics. Concretely, it contemplates the following aspects: knowledge; values, beliefs and goals; motivational orientations; and professional self-regulation skills. In the case of knowledge, the COACTIV model adopts Shulman's construct of pedagogical content knowledge or PCK and broadens this definition adding organizational and counselling knowledge.

Other personal variables of teacher-students have been seen to be related to the decision of using technology in their teaching practice, such as positive attitudes toward technology and personal control over the decision to use technology [5]; or to the real use of technology, such as perceived competence using ICT for teaching, availability of computers, beliefs

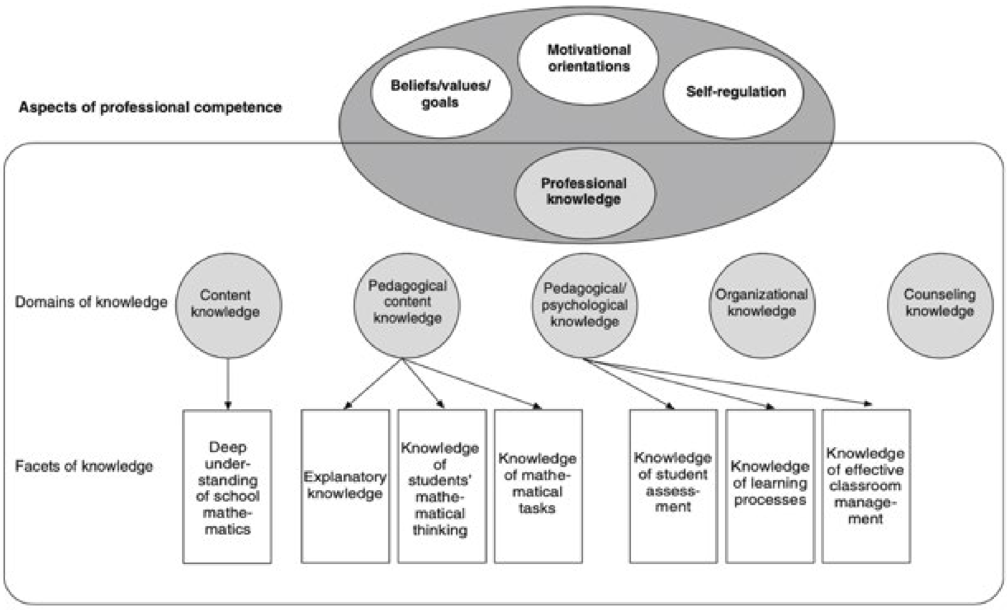

Figure 2: COACTIV model taken from Baumert and Kunter [4]

about the effect of computers, constructivist forms of teaching and learning [6], self-efficacy and value beliefs [7, 8], or intentions to use Meaningful Learning approaches [9].

About the knowledge that teacher-students should have for teaching with technology, one of the most cited models is the technological, pedagogical and content knowledge, or TPACK, developed by Koehler and Mishra [10]. The TPACK model was built also from Shulman's construct of pedagogical content knowledge or PCK. Their authors aimed to explain the three key components of teacher knowledge that teachers need to develop and consider when integrating technology in their practice to produce effective teaching with technology. According to this model, the types of knowledge that need to be considered are technology, pedagogy, and content knowledge, as well as the interactions between all types of knowledge, and knowledge about the context (see Figure 3). The TPACK model has shown to be useful to increase teacher-students' confidence and understanding of digital pedagogies [11]. Furthermore, it has been seen that it can be developed through active involvement in teaching using technology [12].

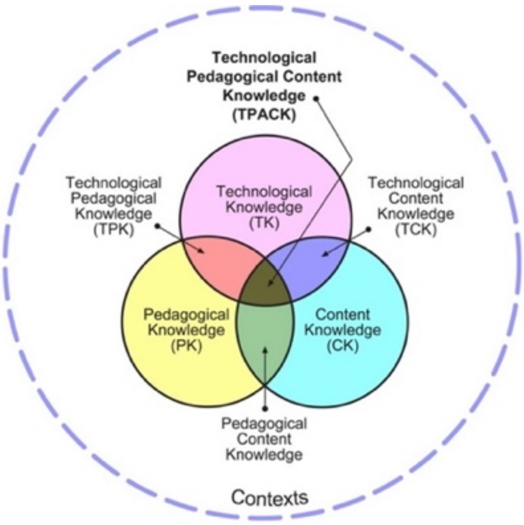

Figure 4: TPACK model taken from Koehler and Mishra [10]

In an attempt to unite the Competence Viewed as a Continuum model, COACTIV and TPACK, [13] developed the Developmental Model of Teacher Professional Competence (DevTPC). Although the author developed it as a framework for teaching foreign language online, it still offers potential uses in other fields (see Figure 4).

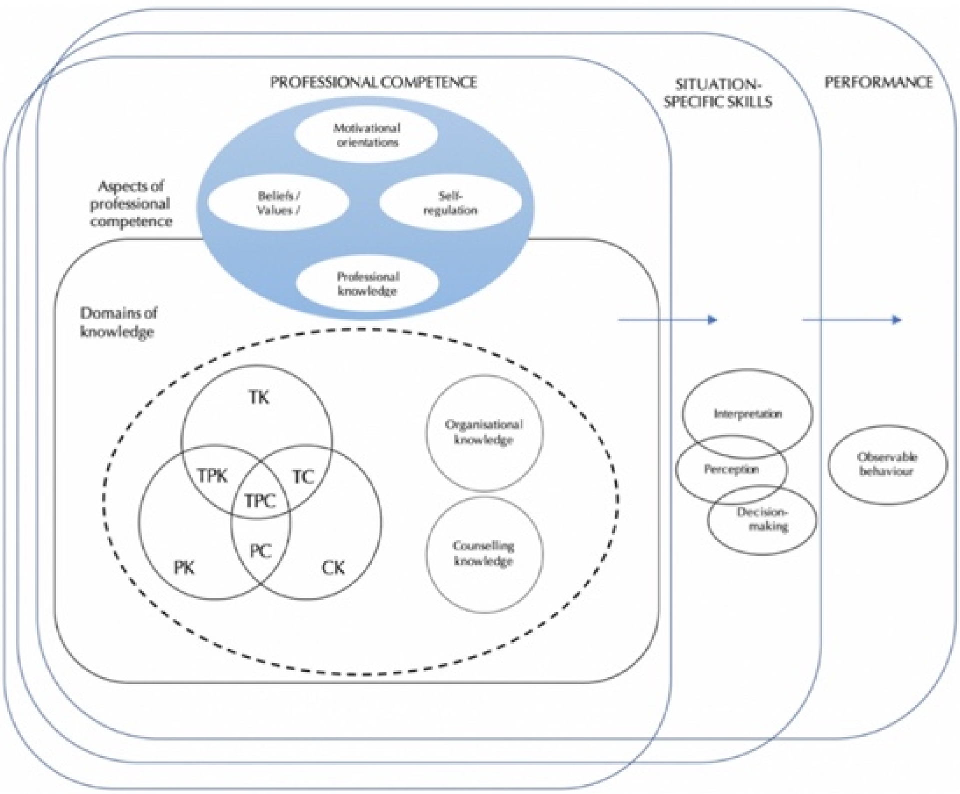

Figure 3: DevTPC model taken from Stadler-Heer [13]

Regarding teaching quality, three basic dimensions have been defined to analyse teaching quality: instructional, organizational and emotional support [14, 15]. These three dimensions are linked to variables that are involved in the learning process. The instructional dimension refers to the instructional support given by the teacher to cognitively activate and engage students; the organizational dimension is related to the classroom management and organizational support provided by the teacher to promote academic and social-emotional learning; and the emotional dimension refers to the support that the teacher gives to his/her students to provide a supporting and positive interactions and learning climate.

1.2. Teacher education

Regarding the way that teachers should be trained, different strategies have been implemented to prepare pre-service teachers to integrate technology into their teaching practice. Tondeur et al. [16] carried out a synthesis of qualitative evidence and extracted the key strategies that have been explicitly related to the preparation of pre-service teachers as well as the necessary conditions at the institutional level. With these aspects, the authors built the SQD Model which includes the aspects that should be provided at the micro and institutional level to prepare pre-service teachers (see Figure 5).

Figure 5: SQD Model taken from Tondeur et al. [16]

These are role models, reflection, instructional design, collaboration, authentic experiences, and feedback at the micro-level; and technology planning and leadership, cooperation within/between institutions, training staff and access to resources at the institutional level. Systematic and systemic change efforts, and aligning theory and practice, are related to both levels. Furthermore, in the field of teacher education, it has been seen that field experiences have positive impact on beliefs and intentions to use technology, especially when teacher-students see technology being used by skilled teachers [9, 17].

1.3. Challenges

Many attempts are being done to set good theoretical backgrounds that foster effective teacher higher education in the field of technology-enabled learning. However, most of the proposed models lack a solid scientific basis, as it is challenging to develop scientific studies whose findings are generalizable and consistent with previous research.

In the case of TPACK, despite it is already one of the most used models in research, it is currently entering a new phase of development as an empirical theory. As indicated by Petko [18] this could be a consolidation phase before a new invigoration, or a period of stagnation and decline. In any case, there are still some open questions about this model that would be interesting to investigate.

In the first place, there is no clear agreement whether the three circles of knowledge contribute equally to TPACK or if these types of knowledge can be different in different situations or levels of technology integration [18]. The specific definition of the different factors is not clear, nor is it the relationship between them. As Brantley-Dias and Ertmer note [19], we are also still missing a detailed description of how does TPACK or its components look like in action. Furthermore, an ongoing debate is whether the TPACK model should be considered an integrative or a transformative model. The integrative vision assumes that all components directly contribute to the final TPACK, whereas the transformative vision assumes that only TCK, TPK and PCK contribute to the final TPACK. It is highly important to understand how the components interact between them to provide learning opportunities in teacher training that foster the acquisition of TPACK, meaning that if the model is transformative, activities that focus solely on TK will not contribute to improving TPACK, but TCK and TPK will need to be fostered [20].

Many extensions and combinations of the model have been done, such as ICT-TPCK [21], TPACK-XL [22], or GPACK [23], increasing its complexity while remaining unclear whether they offer better theoretical ground. For this, the DevTPC model [13] offers a new approach for combining different complementary models rather than extensions of TPACK, including personal variables originally part of the COACTIV model [4], and an explanation of how to evaluate competences originally from the Competence as a continuum model [3].

About measuring TPACK, there aren't many valid and reliable tools for doing so, since most of them are self-reports that don't evaluate factual knowledge but self-efficacy beliefs and can be easily biased. Another method that has been used are rubric-based ratings based on lesson plans. Furthermore, TPACK has not been studied in international large-scale, longitudinal nor experimental settings [18]. Furthermore, while it has been stated that TPACK is constituted by what teachers know, what teachers do and their reasons for doing so, in the field of education and technology, very little research has investigated the instructional decisions that teacher-students make, focusing on *how* and *why* [24].

A part of knowledge, it is difficult to conclude what other teacher-student-related variables are important to teaching competence. This is why the COACTIV model [4] refers to an interplay between cognitive and motivational/self-regulatory characteristics. And not only personal aspects are needed, but also those at an institutional level for teacher training. Here is where the SQD Model [16] poses several variables, but further research into these aspects is still needed to know the role that these variables play as a mediator of teacher competence.

2. Current research

2.1. Research aim

As it has been presented in the previous section, there are some challenges in the field of teacher education for media and computer science teaching, especially regarding the theoretical grounds that support specific didactic actions. Therefore, the main aim of this research will be to contribute to the development of theoretical models using teacher-students' internships on media and computer science education as the object of study, proving the validity of these theories. The theoretical models that will be used for research purposes will be TPACK and the COACTIV model for teacher competence, and SQD Model for teaching settings.

2.2. Research objectives and research questions

The objectives that are expected to be achieved during this research and the specific research questions that will be addressed are:

1. Objective 1: To describe the expression of teacher-students' TPACK in action and analyse the relevance of its components.
   1.1. Is self-reported teacher-students' TPACK coherent with observed TPACK?
   1.2. Do all TPACK components relate to the general TPACK?
   1.3. Are all TPACK components related to a good internship project for media and computer science education?
2. Objective 2: To analyse the professional development of teacher-students during an internship in media and computer science.
   2.1. Do teacher-student-related variables change after participating in an internship on media and computer science?
   2.2. Is there any factor (latent variable) that moderates professional development?
3. Objective 3: Investigate the relationships between models (COACTIV, TPACK, SQD Model) and their influence on teaching quality (Three Basic Dimensions model).
   3.1. Is there any relationship between teacher-student-related variables based on the COACTIV and TPACK models?

3.2. Is there any relationship between teacher-student-related variables, internship projects, teaching quality, and training settings?

3. Research methodology

3.1. Research settings

This research will follow a mixed-methods approach, since qualitative and quantitative data will be collected throughout the study in an embedded manner. Confirmatory and exploratory correlation analysis will be followed depending on the research question.

This research will be conducted in the context of the module “Media and IT education” at the University of Teacher Education of Zurich (PHZH – Pädagogische Höchschule Zürich). The students that participate in this module are teacher-students being trained for teaching in the primary education level. The module includes a practical part of 1 ECTS (30 working hours) where students participate in an internship. For this internship, students conceptualize a media or computer science project based on the Lehrplan 21 [25] and implement it in a school. They do this internship in pairs, and work in a class where they have already been doing internships in the past, therefore, they already know the students and the teacher. After the internship, students submit the project documentation and written observations, and they make a presentation. They are graded based on their performance.

The data will be collected on the Autumn Semester 2022 and Autumn Semester 2023. About the sample, 300 students participate in this module each semester, although not all of them are expected to participate in the study.

It is still to be confirmed whether it would be possible to create an experimental condition where a group of students goes through an intervention different than those in the control group. It is also pending of confirmation whether it would be possible to have access to a control group consisting of teacher-students who take part in an internship that is not related to media and computer science education.

3.2. Measurements

The main aspects that will be evaluated are:

a. Teacher-student-related variables
b. Internship projects
c. Training settings

For the evaluation of teacher-student-related variables (a), self-reported questionnaires will be distributed before and after the internships. These self-reports will evaluate their professional competence based on the COACTIV model, which includes knowledge; professional values, beliefs, and goals; motivational orientations and rationales; and professional self-regulation skills. The specific questionnaire to be used for this aim is still to be confirmed. For evaluating knowledge, the TPACK.xs questionnaire [20] will be distributed before and after the participation in the internship. It consists of 28 items, four per each subscale, and has shown a good validity and reliability for assessing teacher-students’ TPACK. However, since self-reports involve certain limitations such as biases due to social desirability and Dunning-Kruger effects, or measuring teachers’ self-efficacy beliefs instead of factual knowledge [18], performance-based measures to collect more factual knowledge will also be used. Concretely, teacher-students’ internship reports, grades, and reports from teachers from the PHZH and the school where the teacher-students did the internship. Other variables such as beliefs about technology or previous experience with technology will also be analysed to allow further exploration.

Regarding the evaluation of their internship projects (b), the related documentation will be treated as qualitative data and will be analysed making use of categories and codes following content and thematic analysis [26]. From this documentation, their knowledge will be analysed using the TPACK model, and teaching quality using the framework of Three Basic Dimensions. To evaluate the level of competency that students acquire, the evaluation grid that teachers already use may be considered. This grid is KoRa (Kompetenzraster) and it measures 12 competence standards required for an optimal teaching competence [27]. Finally, other variables such as technology used, or topics treated will also be analysed to allow further exploration.

For the evaluation of training settings (c), the SQD Model [16] will be used to analyse the conditions provided to pre-service teachers to prepare them for technology use. This will be done asking teacher-students through a self-reported questionnaire. Furthermore, the TPACK.xs questionnaire will be distributed among their teachers to evaluate the level of TPACK among teacher-student's role models.

3.3. Data analyses

Qualitative and quantitative methods will be used to analyse the data indicated above. For the qualitative analysis, thematic and content analysis will be performed. These analysis will be used to identify the different TPACK categories in students' projects, similar to [24], and to analyse their teaching quality.

For the quantitative analysis, correlational and predictive relationship analysis will be used depending on the specific research question being addressed.

The correlational analysis will be:

- Analysis of Variance, ANOVA (qualitative and quantitative variables) for RQ 1.1 and RQ 1.3.
- Independent t-test (quantitative variables, independent measures) for RQ 1.2 and RQ 3.1.
- Dependent t-test (quantitative variables, repeated measures) for RQ 2.1.
- Factor analysis (latent variables) for RQ 2.2.
- (optional) Chi-square independence test (qualitative variables)

On the other hand, the predictive relationship analysis will be:

- Structural equation modelling (multiple regression analysis) for RQ 3.2.

4. Ethical considerations

Since this research involves the collection and evaluation of personal data, an informed consent form will be created to be signed by all participants. The consent form will include information about the research and about the participant's rights, such as opting-out or eliminating their data. The data collected will be coded and pseudonymously treated during the whole research process.

5. Planning

This thesis will be conducted during September 2021 and September 2025. A general overview of the project schedule is as follows.

Year 2021/22:

- Tasks: Literature review and data collection tools selection.
- Output: Paper "The more you know, the more you believe: Examining the influence of self-reported TPACK on teacher's technology-related beliefs" *(data already collected at the University of Zurich)*

Year 2022/23:

- Tasks: Data collection and data analysis.
- Output: Paper "TPACK: reported vs observed; paper COACTIV and TPACK: internal structure of the COACTIV model in media and computer science education"

Year 2023/24:

- Tasks: Data collection and data analysis.
- Output: Paper "Relationships between TPACK and teaching quality; paper Teacher-students' professional development and moderating factors"

Year 2024/25:

- Tasks: Final thesis elaboration.
- Output: Cumulative dissertation.

6. References

[1] European Commission, European framework for the digital competence of educators: DigCompEdu, Publications Office of the European Union, Website, 2017. Accessed: Apr. 21, 2021. [Online]. Available: http://op.europa.eu/en/publication-detail/-/publication/fcc33b68-d581-11e7-a5b9-01aa75ed71a1/language-en

[2] E. van Laar, A. J. A. M. van Deursen, J. A. G. M. van Dijk, and J. de Haan, The relation between 21st-century skills and digital skills: A systematic literature review, *Comput. Hum. Behav.*, vol. 72, pp. 577–588, Jul. 2017, doi: 10.1016/j.chb.2017.03.010.

[3] S. Blömeke, J.-E. Gustafsson, and R. J. Shavelson, Beyond Dichotomies: Competence Viewed as a Continuum, *Z. Für Psychol.*, vol. 223, no. 1, pp. 3–13, 2015.

[4] J. Baumert and M. Kunter, The COACTIV Model of Teachers' Professional Competence, in *Cognitive Activation in the Mathematics Classroom and Professional Competence of Teachers: Results from the COACTIV Project*, M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, and M. Neubrand, Eds. Boston, MA: Springer US, 2013, pp. 25–48. doi: 10.1007/978-1-4614-5149-5_2.

[5] J. H. Watson and A. Rockinson-Szapkiw, Predicting preservice teachers' intention to use technology-enabled learning, *Comput. Educ.*, vol. 168, Jul. 2021, doi: 10.1016/j.compedu.2021.104207.

[6] D. Petko, Teachers' pedagogical beliefs and their use of digital media in classrooms: Sharpening the focus of the 'will, skill, tool' model and integrating teachers' constructivist orientations, *Comput. Educ.*, vol. 58, no. 4, pp. 1351–1359, May 2012, doi: 10.1016/j.compedu.2011.12.013.

[7] I. Backfisch, R. Scherer, F. Siddiq, A. Lachner, and K. Scheiter, Teachers' technology use for teaching: Comparing two explanatory mechanisms, *Teach. Teach. Educ.*, vol. 104, p. 103390, Aug. 2021, doi: 10.1016/j.tate.2021.103390.

[8] S.-L. Cheng, L. Lu, K. Xie, and V. W. Vongkulluksn, Understanding teacher technology integration from expectancy-value perspectives, *Teach. Teach. Educ.*, vol. 91, May 2020, doi: 10.1016/j.tate.2020.103062.

[9] M. J. Nelson and N. A. Hawk, The impact of field experiences on prospective preservice teachers' technology integration beliefs and intentions, *Teach. Teach. Educ.*, vol. 89, Mar. 2020, doi: 10.1016/j.tate.2019.103006.

[10] M. Koehler and P. Mishra, What is Technological Pedagogical Content Knowledge (TPACK)?, *Contemp. Issues Technol. Teach. Educ.*, vol. 9, no. 1, pp. 60–70, Mar. 2009.

[11] D. Maor, Using TPACK to develop digital pedagogues: a higher education experience, *J. Comput. Educ.*, vol. 4, Mar. 2016, doi: 10.1007/s40692-016-0055-4.

[12] J. Voogt, P. Fisser, N. P. Roblin, J. Tondeur, and J. van Braak, Technological pedagogical content knowledge – a review of the literature, *J. Comput. Assist. Learn.*, vol. 29, no. 2, pp. 109–121, 2013, doi: 10.1111/j.1365-2729.2012.00487.x.

[13] S. Stadler-Heer, Introducing German pre-service teachers to remote teaching: Policy, preparation and perceptions of competence development of future foreign language teachers, *Train. Lang. Cult.*, vol. 5, pp. 68–85, Mar. 2021, doi: 10.22363/2521-442X-2021-5-1-68-85.

[14] D. Holzberger, A.-K. Praetorius, T. Seidel, and M. Kunter, Identifying effective teachers: The relation between teaching profiles and students' development in achievement and enjoyment, *Eur. J. Psychol. Educ.*, no. 34, pp. 801–823, 2019.

[15] A.-K. Praetorius, E. Klieme, B. Herbert, and P. Pinger, Generic dimensions of teaching quality: the German framework of Three Basic Dimensions, *ZDM*, vol. 50, no. 3, pp. 407–426, Jun. 2018, doi: 10.1007/s11858-018-0918-4.

[16] J. Tondeur, J. van Braak, G. Sang, J. Voogt, P. Fisser, and A. Ottenbreit-Leftwich, Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence, *Comput. Educ.*, vol. 59, no. 1, pp. 134–144, Aug. 2012, doi: 10.1016/j.compedu.2011.10.009.

[17] İ. Reisoğlu and A. Çebi, How can the digital competences of pre-service teachers be developed? Examining a case study through the lens of DigComp and DigCompEdu, *Comput. Educ.*, vol. 156, Oct. 2020, doi: 10.1016/j.compedu.2020.103940.

[18] D. Petko, Quo vadis TPACK? Scouting the road ahead, Jun. 2020, pp. 1349–1358. Accessed: Nov. 14, 2020. [Online]. Available: https://www.learntechlib.org/primary/p/217445/

[19] L. Brantley-Dias and P. A. Ertmer, Goldilocks and TPACK: Is the Construct 'Just Right?,' *J. Res. Technol. Educ.*, vol. 46, no. 2, pp. 103–128, Dec. 2013, doi: 10.1080/15391523.2013.10782615.

[20] M. Schmid, E. Brianza, and D. Petko, Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model, *Comput. Educ.*, vol. 157, Nov. 2020, doi: 10.1016/j.compedu.2020.103967.

[21] C. Angeli and N. Valanides, Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK), *Comput. Educ.*, vol. 52, no. 1, pp. 154–168, Jan. 2009, doi: 10.1016/j.compedu.2008.07.006.

[22] M. M. Saad, A. M. Barbar, and S. A. R. Abourjeili, TPACK-XL Framework for Educators and Scholars: A theoretical Grounding for Building Preservice Teachers ICT Knowledge Base, p. 21, 2020.

[23] E. R. Urban, M. Navarro, and A. Borron, TPACK to GPACK? The examination of the technological pedagogical content knowledge framework as a model for global integration into college of agriculture classrooms, *Teach. Teach. Educ.*, vol. 73, pp. 81–89, Jul. 2018, doi: 10.1016/j.tate.2018.03.013.

[24] C. R. Graham, J. Borup, and N. B. Smith, Using TPACK as a framework to understand teacher candidates' technology integration decisions, *J. Comput. Assist. Learn.*, vol. 28, no. 6, pp. 530–546, 2012, doi: 10.1111/j.1365-2729.2011.00472.x.

[25] Lehrplan 21. https://zh.lehrplan.ch/index.php?code=b|10|0&la=yes (accessed Apr. 20, 2021).

[26] M. Vaismoradi, H. Turunen, and T. Bondas, Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study, *Nurs. Health Sci.*, vol. 15, no. 3, pp. 398–405, Sep. 2013, doi: 10.1111/nhs.12048.

[27] S. Biaggi, H. Andreas, and M. Kramer-Länger, Kompetenzraster Berufspraktische Ausbildung PH Zürich: Primar-stufe Quest-3. Version 2.0., Zürich: Pädagogische Hochschule Zürich, 2021.

Learning to Program - Programming to Learn: Technology Supporting Digital, Physical and Social Learning in Schools

Kristina Litherland

University of Oslo, P.O Box 1092, Blindern, 0312 Oslo, Norway

Abstract

The purpose of this project is to provide a deeper understanding of programming pedagogic practices by studying two cases of programming in school, providing two different entry points to learning of and with computer programming. The cases represent two approaches to technology enhanced learning of programming, namely screencasts and so-called "makerspaces", but also how programming as a technology itself may enhance learning. Using qualitative research methods, my aim is to develop theory and practice related to programming pedagogy. Preliminary results show that both screencasts and makerspaces are potentially useful tools for learning programming, and that programming may be a useful learning tool in itself. However, these findings need to be explored and refined further.

Keywords 1

Computer programming, interdisciplinarity, screencasts, makerspaces, socio-cultural perspective

1. Introduction

The autumn of 2020 marked the starting point of the new national curriculum in Norwegian primary and secondary education (years 1 to 10), known as "the Renewal of Subjects" [1, author's translation]. One of the new aspects of the curriculum is the explicit inclusion of computer programming in several subjects, specifically mathematics, science, music, and arts and craft; all of which are mandatory subjects for all students. Computer programming has been an elective subject in Norwegian secondary schools since 2016, but with the new curriculum, all students are obliged to learn to program as part of their mathematics course so they can successfully use programming as a tool in both mathematics and other subjects. This provides several challenges, but also some opportunities. One such challenge is that teachers must learn both computer programming and how to integrate it into their subjects, even though there is little knowledge on how this is best done [2]. On the other hand, programming may provide the opportunity to engage students in interdisciplinary activities and problem solving in several subjects [3].

The Nordic approach to programming in school, where programming is integrated into other subjects [4], is fundamentally different to approaches seen in other Western countries' educational systems where programming is organised as separate subjects (see e.g. [5]). The new, Norwegian curriculum and the existing programming courses provide an opportunity to study programming *for* the subjects versus programming *as* a subject. One rationale for the importance of learning how to program at a basic level is the idea that all members of society need an understanding of the role of programming in the digital world that surrounds us (e.g. what is an algorithm and how can it be used to deliver personalised ads). However, not all students need professional knowledge on how to create industrial-strength computer programs. In the Nordic countries,

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: Kristina.litherland@iped.uio.no
ORCID: 0000-0001-9694-1291

there is an emphasis on programming as a bridge between subject domains, e.g. mathematics and natural science, and statistics and social science.

The aim of this PhD-project is to provide a deeper understanding of programming pedagogic practices in Norwegian schools by studying two cases providing two entry points. The cases represent different approaches to technology enhanced learning of and with programming described in detail later in this paper. Note that my project concerns both learning of conceptual knowledge of programming and other subjects, and how technological tools can support this learning. I view programming skills themselves as technological learning tools.

The PhD-project overall is guided by the following research question with two sub-questions, which, when combined, will provide a basis for elaborating on the main research question. *How do computer programming classes and integrated subject/computing classes compare as interdisciplinary learning arenas?*

1. How does interactive screencast technology support digital and social learning practices in computer programming classes?
2. How are learning processes supported by programming as an intermediate tool between physical making and conceptual knowledge in a digital science classroom?

Using a qualitative, primarily bottom-up approach to explore my research questions, my contribution will be to improve the understanding of the two approaches to programming knowledge development in Norwegian schools. Hence, the aim of the project is not to make statistically generalizable claims, but to give reliable and valid perspectives of development processes observed within the cases at hand. I hope that the project will reveal both challenges and opportunities that are relevant for developing the field of programming pedagogy in school further, and how technical tools are involved in these processes.

2. Theoretical framework

The theoretical framework for the project is grounded in the sociocultural perspective on learning, which considers learning as fundamentally social [8]. A key concept of the sociocultural perspective is that tools mediate learning. According to Vygotsky [8], language itself is the most powerful mediating tool, and researchers should therefore give attention to language use when studying learning. However, language is not the only tool involved in learning computer programming; therefore, also other (computer mediated and non-computational) tools and artefacts will be included as objects for analysis. Computer programming is about creating code a computer can read, which is a technological artefact. However, humans also read, modify, use, and write code, often based on other people's code. I argue that this makes programming an inherently social activity, and that programming should be treated as such. This idea of sociality is in line with Vygotsky's view of learning.

Computer science (CS) education is a broad field and includes CS education at all levels in the educational system: From elementary school to higher education. Nygaard [9] claims the term computer science is too narrow, as it places too much emphasis on the computer itself and does not cover all (e.g. social) aspects of the field. I choose to use the term *programming pedagogy,* as using a verb (programming) makes the term more process/action oriented, to cover the field of teaching and learning to program in a wide sense, including programming concepts, practices and perspectives [10].

This theoretical perspective will frame my analysis by providing a focal point on knowledge development over cognitive assessment. Potential findings relate to observed classroom episodes where the use of tools (e.g. language, gestures, and digital tools) are involved in this development. Since programming in Norwegian schools is a new phenomenon, there is a need to better understand what is happening during programming classes/classes with programming and what the potentials are.

3. Programming in school

The idea of using programming in school is not new and often dated to Seymour Papert's 1980 book *Mindstorms* [3] and his concept of "Turtle Geometry". At the time, Papert and his team at Massachusetts Institute of Technology had recently developed a text-based programming language called Logo. Papert had grand ideas about how children could learn mathematics and geometry hands-on, but also how they could learn to think, by using Logo and constructing programs [11]. However, later research has criticised some of the claims by finding that a programmer's knowledge and experience does not always develop into cognitive/higher order skills (see e.g. [12]).

Mitch Resnick, one of Papert's students and leader of the team that developed the most well-known block-based programming language used in education, Scratch, is a champion for an interest-driven approach as a programming pedagogy [13]. Resnick's idea is that children can develop what is often referred to as 21st century skills, such as creativity and collaboration skills, through open ended programming activities, which involve very little upfront teaching. The success of this approach, according to Resnick, relies on the elimination of complicated programming syntax, which is the aim of block-based programming.

From Papert to Resnick the rationale has moved from being quite specific (mathematics and thinking) to talking about more general skills. The Nordic model of programming can be placed somewhere between the two, as programming is placed within subjects but are meant to develop both domain specific and general skills. Waite [2] mentions programming for the subject as a specific context for programming that needs a specific pedagogy. She uses as example the dilemma of how to help students both connect and differentiate between programming and the subject in question. One particular challenge in this regard is how symbols like punctuation marks or equals signs are used in specific ways in programming languages that are not necessarily compatible with other fields, such as mathematics.

In recent years, a growing number of researchers have studied programming pedagogy. The nominal paper by Wing [6] in 2006 is typically credited as the source of the current wave of programming in schools across the world. As a result of this wave, the field of programming in school has gotten an increasingly large mass of available tools and resources (see e.g. [14]). This is also symptomatic for the field of research. There is a high focus on programming languages and environments, but not on what concepts, ideas, or practices the learners are expected to know. In the Norwegian curriculum, concepts such as variables, loops and if-statements are mentioned explicitly, while a more basic concept such as sequencing is not. In addition, no practices, such as debugging, are included.

Lye and Koh [10] found that research on computational concepts dominated over computational practices (e.g. how students solve programming problems), which again dominated over computational perspectives (e.g. how students talk about what programming means to them or the society). Lye and Koh suggest that both teachers and researchers should focus more on practices and perspectives.

Interestingly, from a Nordic perspective, there is little research on what concepts across fields (including, but not limited to mathematics, natural science, arts and crafts, and music) that are suitable to combine with programming, or whether the integration of programming with these fields is more a question of practice integration.

Modern programming pedagogy is influenced by several, sometimes competing, approaches to the topic of how programming should be taught [2]. One of the main questions is how to structure programming classes. Sentance, Waite & Kallia [15] have identified that one of the most common ways is through traditional lecture style lessons, and also that there are several issues with this teaching style. Moving away from the lecture style approach gives way for more student-active approaches, where students can be encouraged to talk and use other tools.

In the programming industry, using spoken language to debug code was popularised under the term "rubber-duck debugging" back in 2000 [16]. Little research has been done in this field of "talking about code" and reading it aloud in professional and educational settings. Based on the premises of coding being a social activity [9] and that language is one of the most important tools for learning [8], this is a gap in the literature. Some work has been done, however, and several researchers point to the importance of using spoken language to bridge programming activities [10, 15, 17].

The few existing studies have promising results. In their research on what they call code phonology, Hermans, Swidan and Aivaloglou

[18] found that there was a correlation between a student's ability to read code consistently and accurately out load and their general programming knowledge. Kluge et al. [19] found that students could present their own code using screencasts and that the presentations provided a more detailed perspective of the students' understanding than the code would on its own.

Another student-active and interest driven approach is the use of makerspace methodology [20]. Makerspace methodology follows in the line of Papert's learning theory, where students are thought to learn through the construction of physical and digital objects.

Throughout the past decades, we have seen several ideas about what students can learn through programming. They include thinking skills, subject specific and general skills, as well as to teach students about our "digital world". However, most of the research on programming is based on programming for the sake of programming, i.e. to educate professional developers. The Nordic approach assumes that programming can contribute to the learning of other subjects. As is the case with many programming pedagogical topics in school contexts, also the field of programming for the subjects is "underinvestigated" [17, p. 42]. One of the most known cases of such research is on Logo and mathematics [21], but there are some more recent examples.

The project ScratchMaths has shown promising results in using Scratch to teach primary school children basic mathematics skills [22]. In their approach, mathematical and programming concepts were taught "simultaneously", using subtle colour coding to help students differentiate between the two subjects and help them see the connections. This is an important point, as Mørch and colleagues [20] found that students do not automatically connect programming concepts with the relevant school subject(s) if this is not explicitly pointed out to them.

As presented in this section, the programming literature has several interesting lines of research. Since I am applying a qualitative, explorative approach in this project, and I am still at an early stage of my project, I prefer to keep an open mind as to what lines I will pursue later based on the affordances of my data.

4. Research design and method

This qualitative research project is based on data from two cases that represent different approaches to programming in Norwegian schools. See Table 1 for reference. Both cases involve the empirical study of programming interventions in Norwegian schools, and follow design-based research methodology [23].

The first case is situated in the elective programming subjects in Norwegian secondary and upper secondary school, and the purpose of the case to explore the first and main research questions. We employed a digital tool called Scrimba, which is an instructional tool, a code editor, a screen recording tool, and a learning management system, and, in our case, a research data collection tool.

Students and teachers from six schools participated in the intervention. We explore the making and use of screencasts (screen recordings) in different ways, for example to structure lessons and in assessment. The screencasts capture the students' programming activities as a process, including how the students describe and discuss their code.

The second case involves underachieving gifted/talented students attending a natural science class intervention where they incorporate programming and making in science. The aim of this case is to explore the second and main research questions. Potential participants are tested using the Wechsler Intelligence Scale for Children (WISC) test, to identify students who can be defined as underachieving gifted/talented students, but this is not emphasised in my PhD project.

During the intervention, the students are invited to make digital and physical programmed artefacts with the aim of developing understanding of natural science concepts. Approximately 40 students participated in the first iteration, and more are recruited for the second iteration, which is starting during the autumn of 2021.

As both research projects are design based projects, I aim to contribute to both theory development and the development of pedagogical practices that are more "hands on" useful for the practice community.

Table 1
Case comparison

	Case 1	Case 2
Student age	13-19	12-16
Programming rationale	Programming as subject	Programming as learning tool
Context	Elective course in school	Elective course for gifted students across schools
Main pedagogical tools	Interactive screencast technology	Makerspace technology
Data collection	Video/audio recordings in classrooms, semi-structured interviews, screencasts from screencasting software	Video/audio recordings in classrooms, semi-structures interviews, screen recordings from digital classroom environment
N (students)	134	~200

4.1. Data collection

Data from both cases is/was collected using participant observation, screen recordings and interviews. Observations are collected using field notes (meta-data), video cameras, microphones, and screen recording software. This will enable me to capture both what the students are saying, with whom they are talking, how they use their bodies/gestures to communicate, what digital and physical objects they are interacting with as well as what they are constructing. It is vital that the students are encouraged to interact and work together in order to capture these conversations. The student assignments are designed for working in pairs to assure that I may collect interaction data, but in the first case, there are also students who have worked alone and have recorded their own, individual screencast explanations.

In both cases, we used (or intend to use) a voice- and tool-focused approach to video recordings, informed by our theoretical perspective. This is achieved by a particular focus on the relative placement of video and audio recording hardware in the classroom, where cameras are placed so that we capture events on the students' screens and the shared physical space between the students and their persons, enabling us to capture e.g. gestures and how the students potentially move the shared laptop computer or other physical tools between them. A table microphone ensures good quality voice recordings.

Interviews held individually and/or in groups using a semi-structured approach, may provide a meta-cognitive perspective.

The first case is formally concluded, meaning no more data is collected. Data collection in the second case started during the autumn of 2020, and there is available data from the pilot project that is relevant [20]. Because of the Covid-19 pandemic, the 2020/2021 academic year interventions in the second case were conducted digitally, providing considerable challenges forcing all case participants to adapt. This has also affected my project and research questions. We have started conducting the next iteration in a physically co-located classroom, which may provide opportunities for comparing the iterations and cases on even more conceptual levels, which I have not started exploring as of now.

4.2. Data analysis

The data will be analysed using a qualitative approach. I will look at interactions themselves (i.e. the contents and organisation of conversations and other social acts) using interaction analysis (IA) [24]. Typically, this means to look for recurring and/or exceptional "episodes" and sequences of turn taking contributing to meaning making, and organising them into themes that conceptualise the events in the episode [25]. However, as the students are interacting with digital and physical tools and may be using gestures (both physically and digitally) to communicate, these actions are also considered parts of the interaction to analyse. This is in line with a Vygotskyan view on mediational tools as essential parts of learning processes.

The primary data therefore consists of the video observations and screen recordings, as these best capture the complex processes we are studying. The interviews are a secondary data source that may support or challenge what we observe in the classrooms.

As the two cases include relatively large amounts of data (tens of hours of video data), it will be necessary to reduce the data to those that are most relevant for the research questions. This means that I will focus on data were the students are actively engaged in programming, over episodes that are e.g. mainly teacher oriented or where the students are engaged in other types of activities.

Both the cases are parts of larger research projects where other researchers employ several analytical tools and data sources to answer different research questions. My project differs in that I employ the same analytical tools across the two cases.

4.3. Research quality

Although there is some overlap, the cases have distinct takes on programming in school. Instead of viewing this as mainly a challenge, the cases provide an opportunity to investigate contrasting approaches to programming pedagogy.

One challenge, particularly about generalisation to the general population of students who are expected to learn programming within the mandatory subjects following the new curriculum, is that the participants do not represent "typical students" in the Norwegian school, as they have all opted in to take part in the elective programming subjects. Furthermore, all the students in the second case belong to the group of underachieving gifted/talented students. This brings about some methodological challenges, but also the opportunity to study programming with students that are likely to be motivated. It is possible to assume the challenges we might experience with the participants can be even bigger when programming is implemented in mandatory education for everyone.

In the second case, the coronavirus pandemic had a big impact on the first iteration of the interventions. This has provided an opportunity to study the learning of science concepts using digital tools such as "Microbits" and programming, in a digital classroom, but there are challenges on how the data from the digital iteration will compare with the second round.

One way we ensure the research quality in the complex case contexts, is by developing codes and then viewing data separately as researchers to ensure a level of inter-coder reliability.

5. Preliminary results and discussion

In this section, I will briefly describe my preliminary findings and discuss these and the current state of the project. I will frame this discussion using the research questions, starting with the sub-questions and moving on to the main research question.

Sub-question 1: How does interactive screencast technology support digital and social learning practices in computer programming classes?

In the first case, we are exploring affordances of different modes of using integrated screencast technology [19]. The most promising results include how making screencast code presentations may create new learning opportunities for the students, as presented in our short-paper [26]. We have observed episodes where students work collaboratively on developing code and how switching to a screencast recording "mode" of working, e.g. creating a screencast as cultural tool, changed how they talked, edited and tested code. Recording a screencast is not simply a representation of a learning process, but is connected to particular cultural practices. This interrelationship between activity framing, talk, code changes and other development actions will be explored further, and is especially interesting for comparison with the case where another level of abstraction is added, namely the explicit goal of subject learning through programming.

Sub-question 2: How are learning processes supported by programming as an intermediate tool between physical making and conceptual knowledge in a digital science classroom?

Although the digital classroom of the Covid-19 pandemic has caused several problems such as technical difficulties, students dropping out, and changes to the activities in the intervention, we have seen signs of how programming may be a bridge between the individual, concrete, physical artefacts the students made, and the social and digital classrooms where interactions and teaching took place. The students could not manipulate other students' physical artefacts or work together on creating common physical artefacts as they would in a physical classroom, but they could share and manipulate code in the online classroom environment [27]. I will continue to explore the role of programming and screen sharing practices as tools for supporting the students' learning.

Main research question: How do computer programming classes and integrated subject/programming classes compare as learning arenas?

With this research question, I intend to compare the two approaches to programming (traditional approach, and Nordic approach), and explore in what ways they differ and how the interdisciplinarity of the Nordic approach is expressed through the students' learning processes, and how this differs from the traditional approach.

In some respects, the pandemic made the cases more similar, as the collaboration activities in both cases were, in large, mediated by what the students saw and did on the screen.

Currently, data from the two cases are being analysed separately, but I intend to do a comparative analysis once I am more familiar with the separate data sets.

Preliminary findings are mostly empirical, but with deeper analysis, I hope to develop these into more refined models or theories, that may contribute both to the research field of learning to program and programming to learn, but also the practice of how and why.

6. References

[1] Norwegian directorate of Education, the, Nye læreplaner – grunnskolen og gjennomgående fag vgo, 2019. URL: https://www.udir.no/laring-og-trivsel/lareplanverket/Nye-lareplaner-i-grunnskolen-og-gjennomgaende-fag-vgo.

[2] J. Waite, Pedagogy in teaching Computer Science in Schools: A Literature Review, 2018. URL: https://royalsociety.org/~/media/policy/projects/computing-education/literature-review-pedagogy-in-teaching.pdf

[3] S. Papert, Mindstorms: Children, computers, and powerful ideas. Basic Books Inc, 1980.

[4] S. Bocconi, A. Chioccariello, J. Earp, The Nordic approach to introducing Computational Thinking and programming in compulsory education. Report prepared for the Nordic@ BETT2018 Steering Group (2018) doi:10.17471/54007.

[5] N. C. Brown, S. Sentance, T. Crick, S. Humphreys, Restart: The resurgence of computer science in UK schools. ACM Transactions on Computing Education 14 (2014): 1–22.

[6] J. M. Wing, Computational thinking. Communications of the ACM 49 (2006): 33–35.

[7] A. V. Aho. Computation and Computational Thinking. Ubiquity symposium (2011) doi: https://doi.org/10.1145/1922681.1922682

[8] L. S. Vygotsky, Mind in society: The development of higher psychological processes. Harvard university press, 1980.

[9] K. Nygaard, Program development as a social activity. In IFIP Congress (1986): 189–198.

[10] S. Y. Lye, J. H. L. Koh, Review on teaching and learning of computational thinking through programming: What is next for K-12?. Computers in Human Behavior, 41 (2014): 51–61.

[11] I. E. Harel, S. E. Papert, Constructionism. Ablex Publishing, 1991.

[12] R. E. Mayer, J. L. Dyck, W. Vilberg, Learning to program and learning to think: what's the connection?. Communications of the ACM 29 (1986): 605–610.

[13] M. Resnick, Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play. MIT press, 2017.

[14] F. J. García-Peñalvo, J. Hughes, A. Rees, I. Jormanainen, T. Toivonen, D. Reimann, M. Tuul, M. Virnes, Evaluation of existing resources (study/analysis). Belgium: TACCLE3 Consortium. 2016 doi:10.5281/zenodo.163112

[15] S. Sentance, J. Waite, M. Kallia, Teaching computer programming with PRIMM: a sociocultural perspective. Computer Science Education 29 (2019): 136–176.

[16] A. Hunt, D. Thomas, The Pragmatic Programmer. Boston: Addison-Wesley, 2000.

[17] S. Grover, R. Pea, Computational thinking in K–12: A review of the state of the field. Educational researcher 42 (2013): 38–43.

[18] F. Hermans, A. Swidan, E. Aivaloglou, Code Phonology: an exploration into the vocalization of code, in: Proceedings of the 26th Conference on Program

Comprehension, 2018, pp. 308–311. ACM.

[19] A. Kluge, K. T. Litherland, P. H. Borgen, G. O. Langslet, Combining programming with audio explanations, in: Proceedings of the 11th International Conference on Education Technology and Computers, 2019, pp. 155–159.

[20] A. I. Mørch, K. T. Litherland, R. Andersen, End-User Development Goes to School: Collaborative Learning with Makerspaces in Subject Areas. In International Symposium on End User Development, 2019, pp. 200–208.

[21] I. E. Harel, S. E. Papert, Software design as a learning environment, Interactive learning environments 1 (1990): 1–32.

[22] L. Benton, P. Saunders, I. Kalas, C. Hoyles, R. Noss, Designing for learning mathematics through programming: A case study of pupils engaging with place value. International journal of child-computer interaction 16 (2018): 68–76.

[23] S. Barab, K. Squire, Design-based research: Putting a stake in the ground. The journal of the learning sciences 13 (2004): 1–14.

[24] B. Jordan, A. Henderson, Interaction analysis: Foundations and practice, The journal of the learning sciences 4 (1995): 39–103.

[25] V. Braun, V. Clarke, Using thematic analysis in psychology. Qualitative research in psychology 3 (2006): 77–101.

[26] K. Litherland, A. Kluge, A. I. Mørch, Interactive Screencasts as Learning Tools in Introductory Programming, in: Proceedings of the 16th European Conference on Technology Enhanced Learning, 2021, pp. 342–346.

[27] R. Andersen, A.I. Mørch, K. T. Litherland, Learning Domain Knowledge using Block-Based Programming: Design-Based Collaborative Learning, in: Proceedings of the 8th International Symposium on End-User Development, 2021, pp. 119–135.

Developing open educational resources to doctoral education training: an educational design research approach

Lorena Sousa

University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

Abstract

This investigation aims at developing an Open Educational Resource (OER) to the learning of research methods in doctoral programs in Technology-enhanced Learning (TEL). Under the methodological approach of Educational Design Research, it consists of three phases: context analysis, development and formative evaluation, and semi-summative evaluation. Preliminary results from the first phase revealed that design-based research is the most used research method in TEL and also the one that PhD candidates and PhD holders need more training. Considering this, in the second phase, the OER prototype about design-based research was designed and developed using the H5P plugin on Moodle, where it was possible to insert some gamification strategies. At first, only a section about one research method was developed, so that this prototype can be formatively evaluated before developing the whole course on research methods. At the moment, the formative evaluation is being planned to encompass three cycles of assessment. In the first cycle, the scientific content will be validated by experts; in the second, a survey will be conducted with master's and PhD students; and finally, there will be focus groups with professors, researchers and PhD students. In the last phase, a semi-summative evaluation of the whole course will be performed to make the last adjustments to the OER and finally implement and disseminate the results in doctoral programs in TEL.

Keywords 1

Open Educational Resources, doctoral education, Educational Design Research

1. Introduction

As information technologies have advanced and been more accessible, a vast number of digital resources have become more available for those involved in education. Teachers have been using the Internet to spread their materials and courses, and content in digital format has largely increased. Yet, most of these materials are not open to be freely reused, shared or remixed. With the purpose of overcoming these barriers, the Open Educational Resource (OER) movement was founded to encourage and enable anyone to reuse and share content in an open manner.

OER can be defined as any teaching, learning or research materials that make use of open licensing that permits their free reuse, remix and sharing for educational purposes [1]. These educational materials must be under open licenses or reside in the public domain, free of copyright restrictions, to give users free permission to adapt and reuse them [2]. Wiley [3] claims that content is open not only when it is freely available to be used in other contexts. It is open when it gives everyone permission to engage with the material through different activities, known as the 5R: retain, reuse, revise, remix, and redistribute. The types of materials can vary from videos, images and textbooks, to podcasts, games, and courses [1].

There are some motivations for educators, institutions and governments to be involved with the development and sharing of OER [4, 5,

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy
EMAIL: lorena@ua.pt (L. Sousa)
ORCID: 0000-0001-5970-4027 (L. Sousa)

6]. Educators, for example, are able to share content as well as reuse and adapt it according to their context, optimizing their time in creating materials from scratch [7]. Consequently, by reusing and sharing these resources, there might be an improvement in their quality, and the costs of content development can be reduced, which can be a benefit to the institutions. From the governmental perspective, OER projects make learning more accessible to society, particularly to nontraditional groups of learners, bridging the gap between non-formal, informal and formal learning [4, 5, 6].

However, according to [8], educators from higher education institutions are still resistant to embracing the use of OERs and open educational practices. Besides, there is a lack of technical skills to select and remix OER appropriately and a lack of awareness regarding copyright issues among academics [5, 7]. A survey conducted by the Doctoral Education for Technology-enhanced Learning (DE-TEL) project has also shown that OERs are not popular among PhD candidates and PhD holders. When asked which learning sources they used to deepen their knowledge on TEL topics, doctoral training topics and research methods, OERs were the least voted, being courses in the PhD program, academic publications and supervisor help among the most voted learning sources.

Nine European universities and the European Association for Technology-Enhanced Learning (EA-TEL) created the Doctoral Education for Technology-enhanced Learning (DE-TEL) project with the aim at identifying the best practices in doctoral programs in TEL, developing a proposal for a new program and developing sustainable Open Educational Resources (OERs) [9]. The OERs will encompass modules on research methods and key topics in TEL, such as Artificial Intelligence in education and mixed and Augmented Reality for TEL.

This thesis, in particular, focuses on the development of OERs to doctoral education training and, as a contribution to the DE-TEL project, the OERs are going to cover the research methods for doctoral programs in TEL. Our main research question is *which characteristics should an OER developed for doctoral education training have in order to make its use more engaging?* and our objectives are:

1. to analyse the use of OERs in doctoral education training;
2. to identify which characteristics can contribute to make OERs an engaging solution to doctoral education training;
3. to develop an OER to the learning of research methods in doctoral programs in TEL;
4. to evaluate the developed OER on research methods in doctoral programs in TEL.

In the following sections the methodological approach and some preliminary results are going to be presented.

2. Research methodology

This investigation is being developed under the Educational Design Research methodological approach. Its planning consists of three phases [10, 11]: (1) context analysis, (2) development and formative evaluation, and (3) semi-summative evaluation. Each phase will be explained in the next subsections.

2.1. Context analysis

In the first phase, named *context analysis*, a systematic literature review (SLR) is going to be carried out. The main goals of this SLR are to analyse the use of OERs in doctoral education training and identify the main challenges and barriers when adopting OERs in higher education, especially in doctoral programs.

Furthermore, a survey will be conducted among PhD candidates, researchers and practitioners who study and/or work in the field of TEL, the context of this study, to identify which characteristics can contribute to make OERs an engaging solution to doctoral education training. The survey will be divided into four sections. In the first section, there will be questions related to personal background. The second section is going to be adapted from [12] and ask how relevant some characteristics are when searching for content for doctoral education training.

Sections three and four will regard the factors and formats that would make the participant more likely to select a particular resource when searching for content. These sections are going to be adapted from a survey developed by the Hewlett-funded OER Research Hub, an open research project based at The Open University (UK) [13]. At the end of each section, there will be an open-ended question in case participants need to add any additional comments.

The data from the closed-ended questions will be analysed through descriptive analysis on SPSS, and the data from the open-ended questions will be analysed through content analysis on NVivo, if necessary.

2.2. Development and formative evaluation

In the second phase, called *development and formative evaluation*, the conceptualization, design and development of the OER prototype will be carried out considering the previous results from the first phase. Since one of the objectives of the DE-TEL project is to develop OERs on research methods and key topics in TEL, this study will focus on the development of OERs on research methods.

First, a prototype is going to be developed. This prototype will go through cycles of formative evaluation with PhD candidates, professors and researchers in the field of TEL, and as feedback is being received, adjustments and improvements will be carried out.

At the moment, we are studying the instruments and techniques and also searching for some validated questionnaires and scales to formatively evaluate the OER prototype. This formative evaluation will probably consist of three cycles, as presented in Table 1. As the feedback is being received from each cycle, adjustments and improvements will be carried out before starting the next cycle.

Table 1
Cycles of the formative evaluation

Cycle	What?	Who?	How?
1st	scientific content	3 experts	message by email
2nd	general aspects	20 PhD students	UEQ + self-design questions
3rd	general aspects	DE-TEL partners and PhD students	focus groups

In the first cycle, there will be a validation of the scientific content of the prototype. Three experts in research methods are going to be contacted via email to validate the content. The main goal of this cycle is to verify if the content is appropriate to the learning of research methods in doctoral programs in TEL and make the necessary adjustments, before starting the second cycle. To guide the experts' validation, there will be a survey with questions asking if the content is useful, relevant, accurate, reliable, sufficient and if it meets learners' needs. There will also be an open-ended question for additional comments.

In the second cycle, the general aspects of the prototype will be evaluated with twenty PhD candidates. They are going to answer a survey consisting of the User Experience Questionnaire (UEQ) and a self-design questionnaire.

According to Díaz-Oreiro et al. [14], although AttrakDiff has appeared five years earlier than the UEQ and is the questionnaire that counts the most uses since 2006, UEQ has surpassed AttrakDiff in uses per year in 2017 and 2018. Conducting a quick search on Scopus using the search query "user experience questionnaire" and "attrakdiff", it is possible to visualize in Figure 1 that this tendency was kept in 2019, 2020 and has also continued in 2021 (data until July).

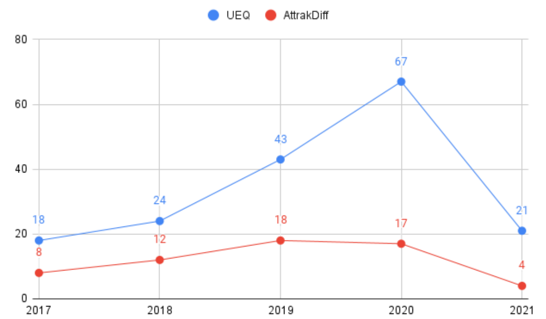

Figure 1: AttrakDiff versus UEQ

Díaz-Oreiro et al. [14] also report that standardized user experience questionnaires were used in combination with other evaluation instruments, such as self-design questionnaires. As we intend to apply a self-design questionnaire as a complement to the standardized questionnaire, we chose to use UEQ over AttrakDiff because AttrakDiff is applied on its website (attrakdiff.de), without the possibility of adding other groups of questions. Using UEQ, we will add it on

LimeSurvey together with other questions from our self-design questionnaire. On the website ueq-online.org, it is possible to download the UEQ in more than 30 languages and a tool is also available on an Excel file, completely free of charge, to facilitate the data analysis.

As a complement to the UEQ, the self-design questionnaire will encompass some open-ended questions, such as the most positive and negative aspects of the prototype in their opinion, and suggestions for improvement. These data will be analysed through content analysis on NVivo.

The data collected in this second cycle will be triangulated with the data from the participants' access to Moodle, where the OER is going to be integrated. On Moodle, it is possible to visualize if the participants accessed the platform, how much time they spent on it, which pages they visualized and interacted with, which tasks they accomplished, etc. The SPSS software is going to be used for statistical data analysis.

In the third cycle, focus groups are going to be conducted. The purpose of these focus groups is to show some preliminary results and shed light on the data collected in the second cycle in order to identify the participants' opinions about the prototype. There will be two focus groups, one with professors and researchers, and another with PhD candidates. Each group will have from six to eight participants, last from 60 to 90 minutes, and will be conducted online, through the Zoom platform. The questioning route will include questions related to the interactive content created with the H5P plugin on Moodle, the 5R activities related to OERs, negative and positive aspects, and others, to make improvements to the prototype.

After the prototype goes through these cycles of formative evaluation, the final version of the OER will go through a semi-summative evaluation before being disseminated in doctoral programs in TEL.

2.3. Semi-summative evaluation

In the third and final phase, after we have a final version of the OER, a *semi-summative evaluation* is going to be conducted among PhD candidates, professors and researchers who study and/or work in the field of TEL. A survey will be conducted to conclude this investigation and make the last adjustments to the OER if necessary. The data will be analysed using SPSS and NVivo. Finally, the OER is going to be disseminated in the doctoral programs in TEL in Europe.

Figure 2 summarizes the methodological design of this research:

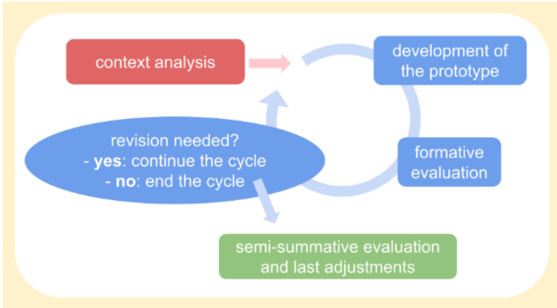

Figure 2: Methodological design

3. Preliminary results

This section will present some preliminary results regarding the development of the first OER prototype on research methods in TEL. This first version is being developed using the H5P tool and plugin on Moodle to test the possibilities of tools that might be useful for the development of OER prototypes.

A survey was conducted by the DE-TEL project to collect information on the current practices and challenges of doctoral education in TEL and find out what topics are useful but have few educational resources. The survey was conducted among students, PhD candidates, researchers, practitioners who study and/or work in the field of TEL, between December 2020 and March 2021, through the online survey tool LimeSurvey whose link was available on the DE-TEL webpage (ea-tel.eu/de-tel/survey). The DE-TEL partners are using SPSS and Tableau to analyse the collected data.

Preliminary results have revealed that 229 participants from 40 different countries, most of them from Europe, answered the survey. When asked to select the item that best described the general methodological approach of their PhD research, PhD candidates and PhD holders reported that design-based research was the most used research method, followed by quantitative and qualitative methods, as can be seen in Figure 3. Regarding the research methods that they need more training, design-based research was also the most selected research method by PhD candidates and PhD holders, followed by quantitative and qualitative methods as well.

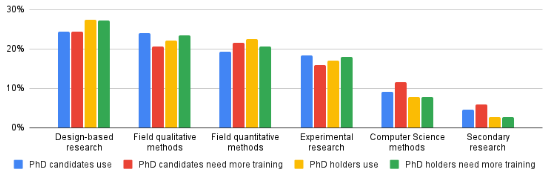

Figure 3: Research methods use and training needs (source: data from the DE-TEL project)

As this research aims at developing OERs to the learning of research methods in TEL and the preliminary results showed that design-based research is the most used research method and also the one which PhD candidates and PhD holders need more training, a prototype of the OER module about design-based research is being designed and developed using H5P tool.

H5P tool (h5p.org), an abbreviation for HTML5 Package, is a completely free and open technology, which enables anyone to create, share and reuse interactive HTML5 content more efficiently, without the need for any technical knowledge.

H5P makes it easy to create rich interactive content by providing several content types for various needs. It is possible to create videos enriched with interactions, presentations with interactive slides, drag and drop tasks with images and text, images with multiple information hotspots, single or multiple choice questions, interactive books integrating several content types, and many others.

Figure 4 shows an example of the content type named *drag the words*, where it is possible to create text-based drag and drop tasks. In this activity, learners are asked to drag the characteristics of design-based research and drop them into the correct explanation. Then, they can check their answers to see how many responses they got right and a score is generated. They can also choose between retrying the task or visualizing its solution. Figure 4, for instance, presents the solution with the correct responses.

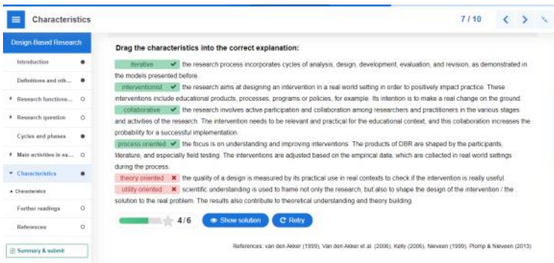

Figure 4: Example of the content type called *drag the words*

The content type that was adopted in the creation of this OER prototype on design-based research was the *interactive book*. The H5P interactive book content type allows authors to create courses, books or tests, combining various interactive content types inside of it, such as interactive videos, course presentations, questions and much more, through multiple pages. Figure 4 illustrates a part of the page about the characteristics of design-based research. On the left-hand side of the image, it is possible to visualize the contents of this interactive book. The numbers in the top right-hand corner of the image indicate the actual page and the total pages of the book, respectively.

At the end of the interactive book, there is a report displaying the learner's progress throughout the book (Figure 5). There is the *total score*, which is the number of points scored by the learner from his/her correct answers to the interactive questions; the *book progress*, which is the percentage of the visualized pages and the performed interactions with the content (it is not possible to get 100% of *book progress* only visualizing the pages); and the *interactions progress*, which is the percentage of the content that the learner interacted with. On the last page of the interactive book, there is also a summary that shows the details of the interactions from each page.

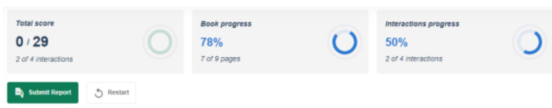

Figure 5: Report of an interactive book

H5P content can be integrated into other platforms, such as Canvas, Blackboard and Moodle. This content about design-based research, specifically, was integrated on the open Tech4Comp platform (moodle.tech4comp.dbis.rwth-aachen.de/), on

Moodle, since it is the platform that is being used by the DE-TEL project. It is also possible to create content using the H5P plugin on Moodle. Thus, some editing and complement to this material were performed directly on Tech4Comp Moodle platform.

With this prototype, we intend to insert some OER characteristics according to the answers from the survey which is going to be carried out in the *context analysis* phase. PhD candidates, researchers and practitioners are going to identify which characteristics can contribute to make OERs an engaging solution to doctoral training and we are going to insert these characteristics into the prototype to see how they work.

4. Final considerations

With this investigation, we expect to contribute to the practical and theoretical understanding of the process related to the development of technological solutions and innovations to the area of TEL. Design-based Research (or Educational Design Research) is the most used research method in TEL and its process brings both theoretical and practical contributions to the area.

Regarding the practical results, we hope that the developed OER can be a useful tool to the teaching and learning of design-based research, that it helps PhD candidates to deepen their knowledge on this research method, and that its characteristics can contribute to making its use more engaging.

Theoretically, we expect that the developed OER can raise awareness of the importance of the adoption and spread of OERs in education, mainly among doctoral programs, and that this study can support the development of other solutions and innovations to the field of TEL.

5. Acknowledgements

I would like to express my gratitude to my supervisors, Professors Luís Pedro and Carlos Santos. This paper and the research behind it would not have been possible without their support, guidance and valuable comments.

This project has received funding from the European Union's Erasmus Plus programme, grant agreement 2019-1-NO01-KA203-060280.

6. References

[1] UNESCO, Guidelines on the development of open educational resources policies, 2019. URL: http://oasis.col.org/bitstream/handle/11599/3455/2019_Guideliness_OER_Policy_final_COL_web.pdf?sequence=4&isAllowed=y

[2] D. Wiley, T. J. Bliss, M. McEwen, Open Educational Resources: A Review of the Literature, in: J. M. Spector, M. D. Merrill, J. Elen, M. J. Bishop (Eds.), Handbook of Research on Educational Communications and Technology, 4th. ed., Springer, New York, NY, 2014, pp. 781–789. doi: 10.1007/978-1-4614-3185-5.

[3] D. Wiley, Defining the "open" in open content and open educational resources, 2014. URL: https://opencontent.org/definition/

[4] J. Hylén, Open Educational Resources: Opportunities and Challenges, OECD's Centre for Educational Research and Innovation, Paris, France, 2006.

[5] OECD, Giving Knowledge for Free: The Emergence of Open Educational Resources, Centre for Educational Research and Innovation, Paris, France, 2007.

[6] S. D'Antoni, Open Educational Resources: reviewing initiatives and issues, Open Learning: The Journal of Open, Distance and e-Learning 24 (2009) 3–10. doi: 10.1080/02680510802625443.

[7] C. Hodgkinson-Williams, Benefits and challenges of OER for higher education institutions, Centre for Educational Technologies, University of Cape Town, Cape Town, South Africa, 2010.

[8] A. García-Holgado, F. J. García-Peñalvo, C. Higuera, A. Teixeira, U. Ehlers, J. Bruton, F. Nascimbeni, N. P. Zea, and D. Burgos, Promoting Open Education Through Gamification in Higher Education: the OpenGame project, in: Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality, TEEM'20, ACM, New York, NY, 2020, pp. 399–404. doi: 10.1145/3434780.3436688.

[9] M. Fominykh, E. Prasolova-Førland, DE-TEL - A European initiative for Doctoral Education in Technology-Enhanced

Learning, 2020, ERCIM NEWS 120, Special Theme: Educational Technology.
[10] S. McKenney, T. C. Reeves, Conducting Educational Design Research, Routledge, New York, NY, 2012.
[11] T. Plomp, Educational Design Research: an Introduction, in: T. Plomp, N. Nieveen (Eds.), Educational Design Research - Part A: an Introduction, Netherlands Institute for Curriculum Development (SLO), Enschede, the Netherlands, 2013, pp. 11–50.
[12] J. Henriques, Catálogo de características para análise e avaliação de Recursos Educacionais Abertos (REA): ferramenta de avaliação no formato checklist, Universidade Aberta, Lisboa, Portugal, 2016.
[13] R. Farrow; R. Pitt; B. de los Arcos; L. Perryman; M. Weller, P. McAndrew, Impact of OER use on teaching and learning: data from OER Research Hub (2013–2014), British Journal of Educational Technology 46 (2015) 972–976. doi: 10.1111/bjet.123410.
[14] I. Díaz-Oreiro, G. López, L. Quesada, L. Guerrero, UX Evaluation with Standardized Questionnaires in Ubiquitous Computing and Ambient Intelligence: A Systematic Literature Review, Advances in Human-Computer Interaction (2021). doi: 10.1155/2021/5518722.

Smart Groups: Group orchestration in synchronous hybrid learning environments

Adrián Carruana Martín, Carlos Alario-Hoyos and Carlos Delgado Kloos

Universidad Carlos III de Madrid, Av. de la Universidad, 28911 Leganés, Madrid, Spain

Abstract

This PhD is framed within the fields of the Smart Learning Environment, collaborative learning and the impact of the pandemic on education. Within this framework, a research opportunity has been found in group orchestration. Education institutions have encountered problems when switching from onsite to online or hybrid learning modes. The tools that teachers and students were used to using were not adapted to the new circumstances. This created several problems, such as teachers and students spending unnecessary time on the activities. Therefore, this PhD proposes techniques and resources to deal with these new emerging problems. One of these resources is Smart Groups, a tool for group orchestration in hybrid learning environments. This tool facilitates and automates many of the orchestration tasks by taking into account the position of the student. It takes into account the safety distance when making decisions and warns users if they do not comply. Finally, Smart Groups has the advantage of remaining useful and performing their tasks in both online or onsite environments.

Keywords

Hybrid learning, Collaborative learning, Orchestration, Smart learning environment, Indoor positioning.

1. Introduction

Terms like Smart Education or Smart Learning Environment (SLE) showed up in the literature about 2014 [1]. In 2019, the definition of these terms was still unclear and there was discussion about it [2]. This happened because of the need to have artificial conceptual aids to create a better idea in a context full of new buzzwords. These terms were influenced by the so-called Industry 4.0 hence its terminology of "Smart" [3]. These terms and works were increasing all over the world [4]. But the works related to these terms had a boom with the arrival of COVID-19 in 2020 [5]. Moreover, the pandemic has led to the emergence of more work on learning in online or hybrid environments. Hybrid learning environments are understood as those in which there are students in the classroom and others online, synchronously [6].

These hybrid learning environments have encountered problems when carrying out collaborative learning activities. These problems were mainly orchestration problems, the amount of time and the lack of specific resources to carry out collaborative activities [7]. For this reason, some online communication applications, such as Skype or Google Meet, started to make changes to adapt to the new circumstances. Some of these changes include increasing the number of users allowed per meeting and improving performance. In addition, some new applications have emerged, such as Zoom, Blackboard or Engageli [8]. Some of these applications have been so important that they have become established in different educational institutions. However, these

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: acarruan@inf.uc3m.es (A. 1); calario@it.uc3m.es (A. 2); cdk@it.uc3m.es (A. 3)
ORCID: 0000-0002-1517-5423 (A. 1); 0000-0002-3082-0814 (A. 2); 0000-0003-4093-3705 (A. 3)

applications have been rather focused on online environments, maintaining some problems in hybrid learning environments. Of these problems, the ones that stand out the most are those related to collaborative learning, such as group orchestration or indoor positioning of students to ensure safe distance [9].

1.1. Research problem

SLEs have worked well in conjunction with collaborative learning [5]. Also, SLEs have been used to try to solve orchestration problems with positive results [10]. In addition, SLEs have been used to try to improve online education [11]. But there is little work using SLEs in synchronous hybrid learning environments. Therefore, the advantages of SLEs in these hybrid environments have not been demonstrated.

In addition, hybrid learning environments are becoming more popular with the pandemic [5]. New works are emerging on collaborative learning in these hybrid environments [12]. But most of these works have a theoretical approach, so there are no results for practical use. Analysis of these works highlights the group orchestration problems that occur in hybrid learning environments [6].

Therefore, a research gap can be identified in collaborative learning and its orchestration in hybrid learning environments. Collaborative learning activities that have these orchestration issues include those in which Collaborative Learning Flow Patterns (CLFPs) are used [13]. CLFPs have shown good results as a way to promote collaborative learning [14] but there is still margin for research when CLFPs are combined with hybrid learning environments.

Furthermore, the pandemic has added new factors to take into account when creating on-site groups, such as safety distance. In some places, the grouping of people would not be allowed if the safety distance cannot be maintained [15]. Taking this factor into account would ensure that collaborative activities would not have to change their dynamics because of this health rule if necessary.

When solutions from previous publications are reviewed, these only address part of the problem, for example, one solution found was the use of robots in the classroom for the "physical" presence of people who are online for collaborative activities [16]. Other papers work on motivation and satisfaction in synchronous hybrid learning environments [17]. There is also literature focused on evaluating the impact of synchronous hybrid learning environments [18]. However, none of these existing publications considers the existing orchestration overload for the teacher.

Considering all these issues, a possible solution would be to develop a tool with the characteristics of an SLE to try to solve orchestration problems, such as group creation, group management or communication. In addition, this solution could include collaborative learning techniques that make use of CLFPs [13]. CLFPs mean a more structured collaboration when the teacher is going to carry out collaborative learning techniques. For some specific cases, collaborative learning techniques using CLFPs give better results than collaborative techniques without CLFPs [14]. For the identification of cases where CLFPs can be used, teachers will be asked to indicate the number of groups or the number of students, if the task to be carried out fulfils certain characteristics (such as if the task to be carried out is divisible, has several solutions and/or has several themes), if teachers are going to take into account the student's previous work data (only if available) to form heterogeneous or homogeneous groups. With this data, a CLFP or the creation of simple groups will be recommended, whichever is best suited to the task. If teachers choose a CLFP, they will have to take into account that they will perform several steps in which the groups will be modified, whereas with simple groups the tasks are always performed with the same group configuration. If teachers want to change the phase of the chosen CLFP, they will have to go to the group management. In the group management the teachers will always be asked if they want to make the change of phase. If the teachers accept, the change of phase will be made, and if the teachers refuse, they can make the necessary changes in the groups. The change of phase of the CLFP will be done automatically. Furthermore, all these functionalities should work in synchronous hybrid learning environments. For these, the tool will provide the necessary resources so that the group can work regardless of where its members are located. These resources can range from a chat room only for the students and another one with the teacher to the possibility of sharing files among all of them. Finally, the tool will take into account the safety distance between users for places that must comply with this health requirement.

As the tool has to be accessible at all times it is conceived as an application for smartphones. For this reason, the target users will be secondary and university students, as students must own a smartphone and be able to operate it without any problems.

The main challenges facing this solution are that the tool helps with orchestration rather than increasing its load, that teachers need to understand CLFPs and that on-site students must use the tool so as not to marginalise those who are online.

1.2. PhD diagram

Figure 1 shows an overview of the PhD, including the context and the research problem, as well as the objectives and expected contributions.

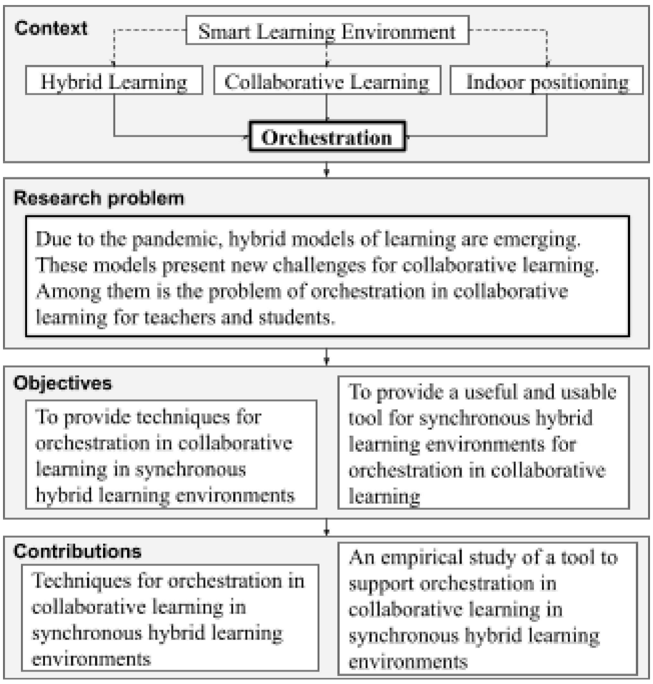

Figure 1: PhD diagram: indicating context, research problem, objectives and contributions

2. Research methodology

Different works were analysed for the research methodology. Among these works, the work of Peffers et al. [20] stood out for its great analysis of different methodologies for information systems. The analysis of this work identified the methodology of Nunamaker et al. [21] as the one best suited to this PhD. This methodology is designed for information systems that need to collect and analyse a lot of information for their elaboration. This methodology takes into account this data analysis in all its phases. These characteristics facilitate the development of the doctorate since there is almost no information on the subject of the doctorate and different ways have to be explored. This methodology consists of different processes which are shown in figure 2.

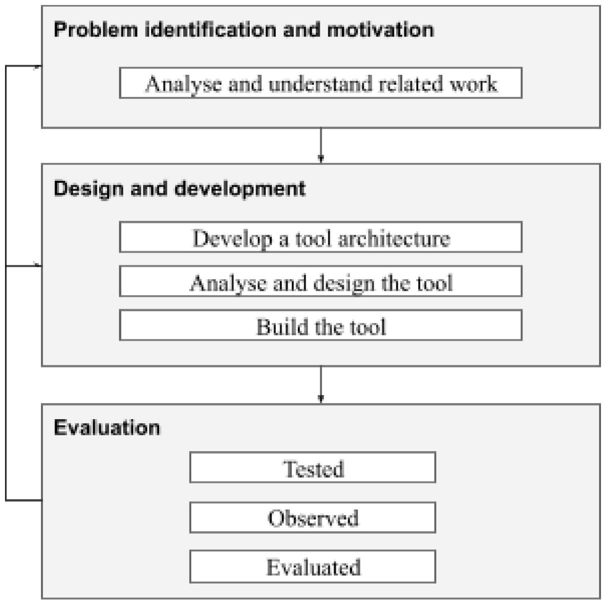

Figure 2: Methodology processes: problem identification and motivation, design and development, evaluation

The first process is problem identification and motivation. In this process, a thorough analysis of previous work is carried out. For this process different research ideas have to be justified, different problems and related research approaches have to be analysed. The second process is design and development. In this process, the architecture of the tool is designed and analysed. Then, according to the analysis, a solution is developed. The last process is evaluation. In this process, the functionality of the tool is tested, observed and evaluated. For testing, a prototype will be made for user observation. The tool will be used in real environments with users for evaluation. The authors define these processes as iterative, i.e. in any process, it is possible to go back to any of the previous processes.

2.1. Problem identification and motivation

A summary of the steps followed in this process of analysis and understanding is shown in Figure 3.

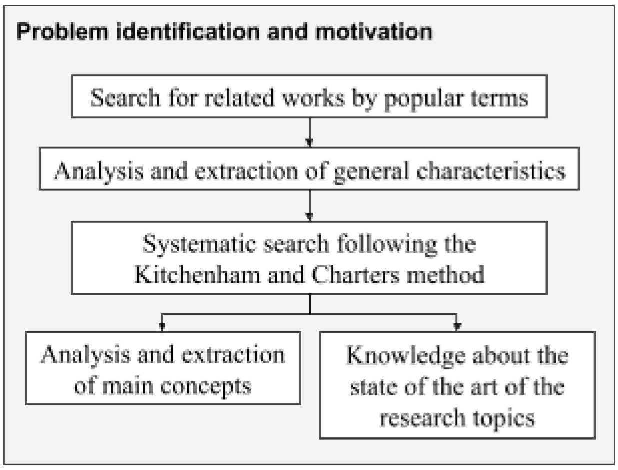

Figure 3: Problem identification and motivation: analyse and understand related work

In the first process of research, a systematic literature review was conducted using popular terms related to SLEs. This search took into account the different terms used in the literature to refer to SLEs, such as Smart Education or Smart Classroom. The other terms were from the educational context, most popular technologies and keywords related to data collection and analysis in smart environments. The next step was another systematic search following the Kitchenham and Charters method [19]. This search focused on empirical work on SLEs. The search analysed the affordances that make a learning environment smart; which technologies are used in SLEs; and in which pedagogical contexts SLEs are used. The paper produced from this joint work with other researchers aims to ensure a relevant knowledge base and a reference for the implementation of future SLEs. Another objective was to try to define SLEs taking as a reference those of Hwang [22], Spector [23] and Koper [24]. This definition was: "*Smart Learning Environments are Technology-Enhanced Learning (TEL) environments that make adaptations and provide appropriate support to learners based on the individual needs and context in order to achieve a better and faster learning*".

While this work on SLEs was being carried out, the COVID-19 pandemic hit the world. As a consequence, some of the classes began to be held with some students on-site and others online in a synchronous manner to respect the maximum capacity allowed in the class. So, it was analysed how SLEs could help in this new situation. SLEs have been shown on several occasions to work well with collaborative learning [5]. In addition, SLEs have also shown good results in solving orchestration problems [10] and in online learning [11]. For these reasons it was decided to try to transfer these benefits to synchronous hybrid education.

The tool must work in both onsite and online learning settings, but especially for hybrid learning. The limitation of the number of students will be given by the architecture that supports the tool, as the automation will help the teacher with the workload. This will allow scaling up by improving the architecture and with only a slight impact on the teacher's workload. Finally, the teacher will have the possibility to modify the groups at any time to achieve the greatest possible flexibility.

2.2. Design and development

A summary of the steps followed in this process of design and development is shown in Figure 4.

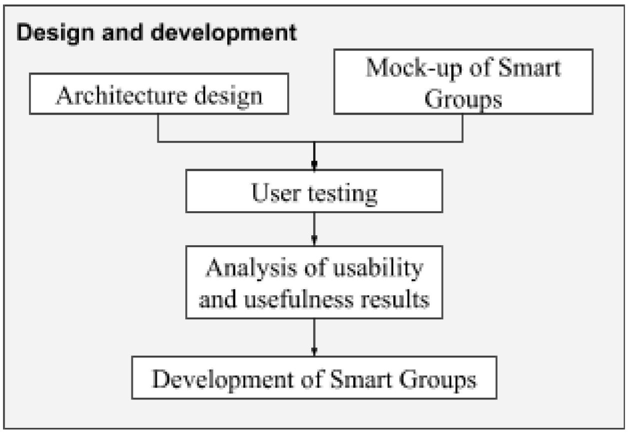

Figure 4: Design and development: architecture, analysis, design and build

After these processes of research and analysis of the related literature, the development of Smart Groups began. In the first stage of development, a design was proposed. But this design did not take into account the ideas of the users, only those of the authors. Therefore, it was suggested to do an early test in order not to have to make changes in the final step of the development of Smart Groups. To test whether this tool was useful and usable for users, an exploratory research study was conducted on a mock-up of the tool. System Usability Scale (SUS) was used to evaluate the usability of Smart Groups [25]. For the usefulness evaluation, interviews were conducted according to the Technology Acceptance Model (TAM) [26].

After this iteration, development of the smartphone application began [27]. Initially, the students' part was developed to detect whether they were in the classroom or not and to show them the map of the classroom according to their group. Then, the teacher's part was developed for the creation and management of groups, and the recommendations of the CLFPs, as can be seen in Figure 5. Once this basic flow was completed, access security, communication tools and file-sharing were introduced. Finally, the user interface was improved and some functionalities were added, such as the search by student name.

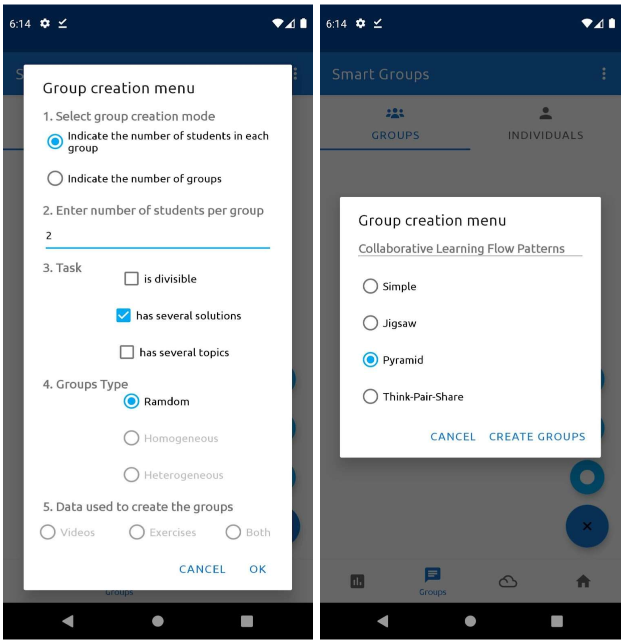

Figure 5: Recommendations of the CLFPs: Teacher form and associated recommendation

2.3. Evaluation

A summary of the steps followed in this process of evaluation and experimentation in a real environment is shown in Figure 6.

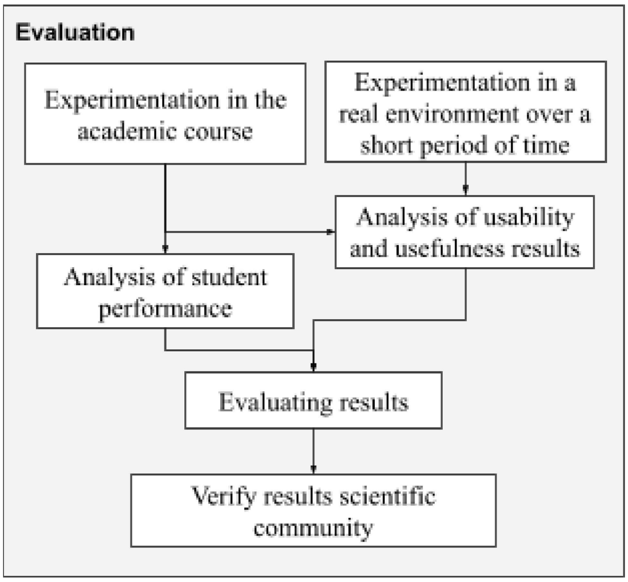

Figure 6: Evaluation: Experimentation, analysis and verification

So far only one iteration of evaluation has been done during development [9]. A SUS questionnaire was administered to 60 users who had performed different activities with the mock-up. These surveys resulted in a mean score of 75.54 out of 100, which is a good result according to SUS. In addition, interviews were conducted according to the Technology Acceptance Model (TAM). These interviews were conducted with 10 teachers who participated in the previous evaluation. The results of the interviews were that the users perceived almost all features of Smart Groups as useful.

A new iteration of the evaluation is currently underway. For the future evaluation, several experiments will be carried out, which will be divided into two types. The first type is of long duration, about four months. A collaborative project will be carried out throughout the whole period in this type of experiment. The second type is of short duration. These experiences will be short, like seminars of a maximum of 2 or 3 days.

From the short-term experiences, it is expected to obtain different approaches to the usefulness, usability, impact of learning and satisfaction of Smart Groups. For this purpose, the SUS [25], TAM [26] and the model proposed by Muñoz-Carril et al. [28] models will be used. In this way, a wider variety of users can be obtained, thus increasing the number of perspectives. Furthermore, this will allow a comparison with the results already obtained in the development phase. In addition, the evaluation of learning impact and satisfaction will provide further information to demonstrate whether Smart Groups is a tool that effectively supports collaborative learning in synchronous hybrid learning environments.

From the long-term experiences, it is expected to obtain the performance, the perception of usefulness, usability impact of learning and satisfaction of the students when using Smart Groups over this long time. For the performance, there will be control groups that will not use the application and the results will be compared to see how much it can influence the performance of the students. For the usefulness and usability part, the same will be done as with the short experiences, with the SUS [25] and TAM [26] models. For the learning impact and satisfaction, the model proposed by Muñoz-Carril et al. [28] will be used. On these results, it will be possible to observe whether there is a difference in using Smart Groups moderately or over a longer time.

Finally, the analysis of these results will be presented in a paper. This paper will be published in a first quartile JCR journal. To confirm that the analysis is done correctly and that it is useful for the scientific community.

3. Future work

This PhD is trying to solve the problem of orchestration in hybrid learning environments, trying to enhance collaborative learning and taking into account security measures for the pandemic. But this is a big problem and there are still issues to be addressed. In addition, some issues are far from the focus of the PhD and therefore have a lower priority to be addressed.

The issue of Learning Analytics has come up a lot during the course of the PhD. So LA is likely to be integrated into the PhD if time permits. This issue can be a good tool to get feedback from students. This information can be used by teachers for decision making, or for gamification issues.

Another issue for the future is gamification. Although some gamification features have been used in this PhD, it is not an issue that has been explored in depth. This issue can contribute to improving collaborative learning. In addition, gamification can facilitate group orchestration by making it a game for students.

Another future work is the incorporation and adaptation of external resources, such as MOOCs or tools for collaborative learning. New resources of this kind come out all the time to solve new problems or to improve old tasks. Therefore, facilitating the incorporation of these resources into a tool in use can help its development and useful life.

An issue derived from the previous one is the incorporation of tasks in Smart Groups. In other words, the teacher can set exercises for the students so that they only need one tool to carry out their collaborative activities.

Finally, this PhD has a practical focus, so it is limited especially in the evaluation part. It is necessary to gather the necessary people for the experimentation, and this is very difficult. Even with all this, it is hoped to be able to improve collaborative learning in hybrid environments and facilitate its use in times of pandemics.

4. Expected contributions

SLEs are slowly growing and are a good research opportunity. There are many problems to be solved in the education of the future. The pandemic has shown that there is much opportunity for improvement. Especially the growth of hybrid and online learning environments. In addition, problems have been encountered in carrying out collaborative learning activities that are time-consuming for both teacher and student.

For these reasons, it is expected that this PhD will make a conceptual contribution to synchronous hybrid learning environments. The aim is to help separate the concept of synchronous hybrid learning environments from that of blended learning so that there is no confusion in the educational community. As part of the empirical contribution, a tool to support orchestration in collaborative learning in synchronous hybrid learning environments will be developed. This tool will seek to enrich collaborative learning with CLFPs and automate the most tedious tasks in group management. In addition, this tool incorporates features to be able to continue collaborative learning in times of pandemic. Finally, an empirical study of how a tool such as Smart Groups can help in these new environments will be conducted.

5. Acknowledgements

This work was supported in part by the FEDER/Ministerio de Ciencia, Innovación y Universidades – Agencia Estatal de Investigación, through the Smartlet Project under Grant TIN2017-85179-C3-1-R, and in part by the Madrid Regional Government through the e-Madrid-CM Project under Grant S2018/TCS-4307 and under the Multiannual Agreement with UC3M in the line of Excellence of University Professors (EPUC3M21), and in the context of the V PRICIT (Regional Programme of Research and Technological Innovation), a project which is co-funded by the European Structural Funds (FSE and FEDER). Partial support has also been received from the European Commission through Erasmus+ Capacity Building in the Field of Higher Education projects, more specifically through projects LALA, InnovaT and PROF-XXI (586120-EPP-1-2017-1-ES-EPPKA2-CBHE-JP), (598758-EPP-1-2018-1-AT-EPPKA2-CBHE-JP), (609767-EPP-1-2019-1-ES-EPPKA2-CBHE-JP). This publication reflects the views only of the authors and funders cannot be held responsible for any use which may be made of the information contained therein.

6. References

[1] J. M. Spector, Conceptualizing the emerging field of smart learning environments. Smart learning environments, 1, (2014). doi: 10.1186/s40561-014-0002-7.

[2] A. Carruana Martín, C. Alario-Hoyos, & C. Delgado Kloos, Smart Education: A Review and Future Research Directions, in: Multidisciplinary Digital Publishing Institute Proceedings. 31:57, 2019. doi: proceedings2019031057.

[3] D. Assante, A. Caforio, M. Flamini and E. Romano, Smart Education in the context of Industry 4.0, 2019 IEEE Global Engineering Education Conference (EDUCON), 2019, pp. 1140-1145, doi: 10.1109/EDUCON.2019.8725057.

[4] Z. T. Zhu, M. H. Yu, & P. Riezebos, A research framework of smart education, Smart learning environments, 3 (2016): 1-17. doi: 10.1186/s40561-016-0026-2.

[5] B. Tabuenca, S. Serrano-Iglesias, A. Carruana Martín, C. Villa-Torrano, Y. Dimitriadis, J. I. Asensio-Perez, C. Alario-Hoyos, E. Gomez-Sanchez, M. L. Bote-Lorenzo, A. Martınez-Monés & C. Delgado Kloos, Affordances and Core Functions of Smart Learning Environments: A Systematic Literature Review. IEEE Transactions on Learning Technologies, (2021) doi: 10.1109/TLT.2021.3067946.

[6] A. Raes, L. Detienne, I. Windey, & F. Depaepe, A systematic literature review on synchronous hybrid learning: Gaps identified. Learning Environments Research, 23 (2020): 269-290. doi: 10.1007/s10984-019-09303-z.

[7] S. Hrastinski, Asynchronous and synchronous e-learning. Educause quarterly, 31 (2008): 51-55. URL: https://er.educause.edu/articles/2008/11/asynchronous-and-synchronous-elearning

[8] M. M. Archibald, R. C. Ambagtsheer, M. G. Casey, M. Lawless, Using Zoom Video conferencing for Qualitative Data Collection: Perceptions and Experiences of Researchers and Participants. International Journal of Qualitative Methods. (2019). doi: 10.1177/1609406919874596.

[9] A. Carruana Martín, C. Alario-Hoyos, & C. Delgado Kloos, Smart Groups: A system to orchestrate collaboration in hybrid learning environments. A Simulation Study. (2021). Manuscript submitted for publication.

[10] C. Delgado Kloos, Y. Dimitriadis, D. Hernández-Leo, P. J. Muñoz-Merino, M. L. Bote-Lorenzo, M. Carrió, C. Alario-Hoyos, E. Gómez-Sánchez, & P. Santos, SmartLET: Learning analytics to enhance the design and orchestration in scalable, IoT-enriched, and ubiquitous Smart Learning Environments, In: Proceedings of the Sixth International Conference on Technological Ecosystems for Enhancing Multiculturality, 2018, pp. 648-653. doi: 10.1145/3284179.3284291

[11] P. Temdee, Smart Learning Environment: Paradigm Shift for Online Learning. In: Multi Agent Systems-Strategies and Applications, IntechOpen, 2020. doi: 10.5772/intechopen.85787

[12] T. Cochrane, J. Birt, N. Cowie, C. Deneen, P. Goldacre, V. Narayan, L. Ransom, D. Sinfield, & T. Worthington, A collaborative design model to support hybrid learning environments during COVID19. ASCILITE's First Virtual Conference. Proceedings ASCILITE 2020 in Armidale, 2020, pp. 84-89. doi: 10.14742/ascilite2020.0119.

[13] K. Manathunga and D. Hernández-Leo, A Multiple Constraints Framework for Collaborative Learning Flow Orchestration, in: Advances in Web-Based Learning – ICWL 2016, Cham: Springer International Publishing, 2016, pp. 225-235. doi: 10.1007/978-3-319-47440-3_25.

[14] D. Hernández-Leo, J. I. Asensio-Pérez, & Y. Dimitriadis, Computational Representation of Collaborative Learning Flow Patterns using IMS Learning Design. Journal of Educational Technology & Society, 8 (2005): 75-89. URL: http://www.jstor.org/stable/jeductechsoci.8.4.75

[15] L. Uscher-Pines, H.L. Schwartz, F. Ahmed, Y. Zheteyeva, E. Meza, G. Baker and A. Uzicanin, School practices to promote social distancing in K-12 schools: review of influenza pandemic policies and practices, BMC Public Health, vol. 18, 2018, pp. 406. doi: 10.1186/s12889-018-5302-3.

[16] W. Cain, J. Bell and Cui Cheng, Implementing robotic telepresence in a synchronous hybrid course, Jul 2016, pp. 171-175. doi: 10.1109/ICALT.2016.79.

[17] N.T. Butz and R.H. Stupnisky, A mixed methods study of graduate students' self-determined motivation in synchronous hybrid learning environments, The Internet and Higher Education, vol. 28, 2016, pp. 85-95. doi: 10.1016/j.iheduc.2015.10.003.

[18] M.M. Alexander, J.E. Lynch, T. Rabinovich and P.G. Knutel, Snapshot of a hybrid learning environment, Quarterly Review of Distance Education, vol. 15, 2014, pp. 9. URL: https://www.proquest.com/scholarly-journals/snapshot-hybrid-learning-environment/docview/1566396191/se-2.

[19] B. Kitchenham, S. Charterset, Guidelines for performing systematic literature reviews in software engineering version 2.3, Engineering, 45:1051 (2007).

[20] K. Peffers, T. Tuunanen, C. E. Gengler, M. Rossi, W. Hui, V. Virtanen & J. Bragge, The Design Science Research Process: A Model for Producing and Presenting Information Systems Research, in: 1st International Conference, DESRIST 2006 Proceedings, 2006, pp. 83-106. doi: 10.2753/MIS0742-1222240302.

[21] J. F. Jr. Nunamaker, M. Chen, & T. D. Purdin, Systems development in information systems research. Journal of management information systems, 7 (1990): 89-106. doi: 10.1109/HICSS.1990.205401.

[22] G. J. Hwang, Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective. Smart Learning Environments, 1 (2014): 1-14. doi: 10.1186/s40561-014-0004-5.

[23] J. M. Spector, Conceptualizing the emerging field of smart learning environments, Smart learning environments, 1 (2014): 1-10. doi: 10.1186/s40561-014-0002-7.
[24] R. Koper, Conditions for effective smart learning environments, Smart Learning Environments, 1 (2014): 1-17. doi: 10.1186/s40561-014-0005-4.
[25] J. Brooke, SUS: a 'quick and dirty' usability. Usability evaluation in industry, (1996) 189-194. URL: http://www.tbistafftraining.info/smartphones/documents/b5_during_the_trial_usability_scale_v1_09aug11.pdf
[26] F. Davis, Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly, 13 (1989): 319-340. doi: 10.2307/249008.
[27] A. Carruana Martín, C. Alario-Hoyos and C. Delgado Kloos, Smart Groups: A Tool for Group Orchestration in Synchronous Hybrid Learning Environments, in Technology-Enhanced Learning for a Free, Safe, and Sustainable World, Cham: Springer International Publishing, 2021, pp. 384-388. doi: 10.1007/978-3-030-86436-1_40
[28] P.-C. Muñoz-Carril, N. Hernández-Sellés, E.-J. Fuentes-Abeledo, and M. González-Sanmamed, Factors influencing students' perceived impact of learning and satisfaction in Computer Supported Collaborative Learning, vol. 174, Dec. 2021, doi: 10.1016/j.compedu.2021.104310.

Sense the classroom: AI-supported synchronous online education for a resilient new normal

Krist Shingjergji[a], Deniz Iren[a], Corrie Urlings[a] and Roland Klemke[a,b]

[a] Open University of the Netherlands 6419 AT Heerlen, The Netherlands
[b] Faculty of Cultural Sciences, TH Köln, Cologne, Germany

Abstract

Following the COVID-19 pandemic, as the user-base of online synchronous communication systems skyrocketed, the shortcomings of synchronous online learning systems became more visible. Any attempt to overcome these shortcomings should be considered worthwhile due to the magnitude of potential impact. Improving the quality and addressing the shortcomings of online education is more important than ever. The goal of this multidisciplinary study that lies in the intersection of the fields of Education Science and Computer Science is to address a number of challenges of online education by incorporating AI. This study focuses on developing methods and means to ethically collect and use non-verbal cues of participants of online classrooms to assist teachers, students, and course coordinators by providing real-time and after-the-fact feedback of the students' learning-centered affective states.

Keywords 1

Technology enhanced learning, learning-centered affective states, affective computing, synchronized learning, artificial intelligence

1. Introduction and motivation

Online learning provides a means of education to students with physical limitations or inconvenience to participate in physical, face-to-face classroom education. During the COVID-19 pandemic, this limitation became relevant for all students. Approximately, 1.2 billion learners were affected by the closure of schools at the time of the pandemic [1] and educational institutions worldwide made a mandatory transition to online/hybrid learning [2]. As the utilization of online learning reached unprecedented levels, the already-known challenges of online education became painfully visible for both students (e.g., feeling of isolation [3]) and teachers (e.g., lack of face to face interaction with the students [4]).

Students' learning experience and performance are highly related to their psychological, physiological, and emotional states [5]. Teachers can notice when students are distracted, confused, tired, etc., and have the opportunity to adjust their teaching approach accordingly [6], and choose appropriate interventions to keep the learning experience of the class optimal. However, many teachers who gave an online lecture have experienced the severe lack of an understanding of the *learning-centered affective states* of students in the classroom, thus, missing opportunities to improve the overall learning experience. This also directly impacts individual students. In online lectures, students are more prone to distractions and use the Internet for purposes unrelated to the educational activity [7]. The lecturers cannot give timely feedback to guide

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: krist.shingjergji@ou.nl (Krist Shingjergji)
ORCID: 0000-0002-8239-9478 (Krist Shingjergji)

the attention since they do not observe the students physically. As a result, the students are left alone to manage their learning experience, stay motivated, and struggle not to fall behind during the educational activity. The underlying reason that leads to these challenges is the communication modality limitations of video conferencing technologies.

In this study, we build on Media Naturalness Theory to examine the limitations of video conferencing as a medium of communication for online, synchronized education. Our objective is to develop artificial intelligence (AI) models to detect a multitude of components of learning-centered affective states (e.g., gestures, micro-expressions, and macro-expression) of the learners, and present the aggregated information to the teacher and the course coordinator in a privacy-protecting manner, and provide the individual information to the students themselves.

The remainder of this paper is structured as the following. Section 2 sheds light on the background and related work. Section 3 lays out the details of the overall research methodology. Section 4 highlights important discussion points such as the theoretical and practical implications, and ethical considerations.

2. Background and related work

In this section we explain the overall methodology that is proposed for this study.

2.1. Communication modalities and Media Naturalness Theory

Human communication occurs in multiple modalities such as voice, speech, facial expressions, and body language [8]. One important type of human communication is the non-verbal communication which is the way of conveying information without the use of words via non-verbal cues i.e., facial expressions and body language [9]. Video conferencing platforms fall short in conveying non-verbal cues among participants. The shortcomings of video conferencing as a communication medium can be analyzed and improved based on the Media Naturalness Theory (MNT). MNT describes the criteria to assess the degree of naturalness of a communication medium that partly relates to the capability of transmitting body language, facial expressions, and natural speech [10]. According to this theory, a reduction in a medium's naturalness may lead to a decrease in learning effectiveness, and a potential increase in ambiguity of the conveyed message [11].

2.2. Learning centered affective states

Many studies that aim to detect the relationship between online learning and emotions by applying emotion recognition techniques, use the basic emotions, namely, happiness, sadness, fear, disgust, anger, and surprise [12]. A plethora of studies that report an accurate mapping among facial expressions and emotions exist in the literature [13], [14], [15]. However, D'Mello in [5] states that the basic emotions are quite infrequent in the context of learning with educational software which raised the need of focusing on the learning-centered affective states, such as *engagement, concentration, boredom, anxiety, confusion, frustration,* and *happiness*. In contrast to emotion recognition, the mapping between facial expressions and learning-centered affective states has been severely understudied [16].

The observable non-verbal cues consist of gestures and body postures (e.g., head-tilt, nod, shake), micro-expressions (e.g., movement of inner eyebrows and lips), other expressions (e.g., smile, frown, confusion), and other activities (e.g., note-taking, active-listening, looking-away) [17]. The state-of-the-art facial-expression recognition (FER) and gesture recognition (GR) models use Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) hybrid networks [18]. These models perform discrete/momentary measurement (i.e., in short intervals), generally on single modality, and they are trained on datasets in which the non-verbal cues are mimicked by actors (i.e., not naturally occurring). As previously mentioned, the detection of constructs other than the six universal emotions[2], such as learning-centered affective states does not have a rich literature. However, the collection of high-quality data for the recognition of learning-centered affective states has been the subject of several studies

[2] sadness, happiness, fear, anger, surprise, and disgust

that have certain important limitations, for instance; focusing only on game-based interfaces [19], being explicit to certain ethnic groups [20], and having a limited target affective set such as the level of engagement on a scale [21], and the lack of interest and boredom [22].

In this study, we will bridge this gap by improving the CNN-RNN hybrids architecturally by introducing attention layers, formulating fitting objective functions, fusing data from multiple modalities, and applying transfer learning to train models with the multi-modal data collected from synchronous online education settings.

3. Methodology

In this section we explain the overall methodology that is proposed for this research.

3.1. Research model

Active and engaged learning is an important model in online higher education. Therefore, this study aims at addressing the motivational and emotional side of online education, by providing information that can assist educators to refine the educational activities that they have devised. Our aspiration is to utilize theories of learning, motivation, and emotion in combination to (1) define the relationship between learning-centered affective states of students and observable non-verbal cues, (2) develop specialized multi-modal AI algorithms for the recognition of learning-centered affective states, (3) and design tools to present this information in an actionable way for teachers and students to improve the learning process respecting the privacy of all participants (Figure 1).

Thus, the research questions of our studies are as follows:

1. Which are the specific non-verbal feedback needs (e.g., facial expressions) of teachers and students in online lectures?
2. How can we automatically detect non-verbal cues and translate them to learning-centered affective states of multiple participants in online, synchronous, educational activities?
3. How can we present this information to teachers in real-time so that they can take actions to positively influence the learning-centered affective states of the students?
4. How can we provide students with this information so that learning-centered affective states are positively influenced?
5. How can we design a system that is ethically sound, that respects privacy concerns and keeps all collected data secure?

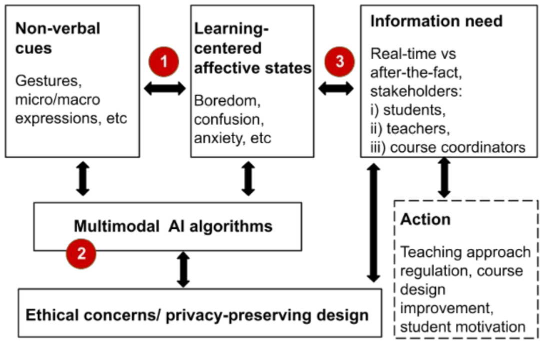

Figure 1: The research model

3.2. Approach

In this study, we will employ Design-Based Research (DBR) and experiments throughout multiple iterations (Figure 2). Teachers and students will be involved in focus groups and co-designing of prototypes [23]. The DBR iterations consist of literature study, requirements elicitation, participatory design, and evaluation of the interventions (i.e., integrated AI models) in pilot studies of online learning. The AI models will be developed through experimentation cycles which comprise data collection, annotation, algorithm development, and model training and evaluation. We will collect data from public-domain video repositories and online lecture sessions recorded by us with the informed consent of participants. The data will be annotated by multiple experts in terms of observed non-verbal cues. Consecutively, we will develop algorithms, train and test FER-GR, and the learning-centered affective states recognition AI models on multiple datasets to ensure generalizability. We will rely on metrics that are commonly used in machine learning, i.e., precision, recall, and F-1 measure to evaluate the accuracy of our models. Data management will be conducted in line with the FAIR data principles [24].

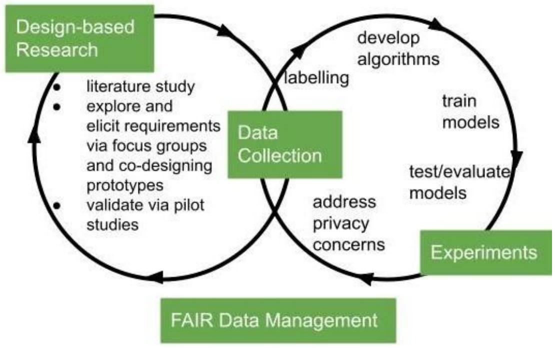

Figure 2: The research approach

We envision the system to provide certain information in real-time and after-the-fact to various stakeholders for different purposes (Table 1). The information flow is targeted at specific educational purposes for each party involved, with short-term and long-term educational benefits.

Table 1
Information flow to the actors of the system

When	Who	What	Why
Real-time	Teacher	Aggregated information regarding the overall learning-centered affective states of students in the classroom.	Teacher may (a) alter the teaching style and/or (b) initiate interventions (e.g., breakout rooms).
	Student	A semiotic indicator that shows their own learning-centered affective states, as well as suitable nudges (e.g., pop questions).	Keep the student engaged and active, positive influence on the learning process and self-regulation.
After-the-fact	Teacher	A report that shows the detected learning-centered affective states of the overall classroom matched to different parts of the educational activity (e.g., slides, activities, interventions) as a timeline.	Improve design of educational activity and delivery style.
	Course Coordinator	Learning-centered affective states trend of a course throughout multiple online educational activities.	Evidence-based course design and ensuring educational quality.

4. Discussion

In this section, we discuss several important aspects of this study including the theoretical and practical implications, the privacy concerns as well as the limitations.

4.1. Theoretical and practical implications

The outcomes of our experiments will potentially allow us to gain a deeper understanding on how learning-centered affective states are indicated by observable non-verbal cues, and how these states can be related to an effective learning experience. Our results will also contribute to the Media Naturalness Theory by extending it to cover widely used video conferencing platforms and tailor it for education scenarios.

The practical outcome of this study will be an analytical platform that is integrated to video conferencing clients of the students and the teachers. The platform will be able to provide feedback both on *real-time* and *after-the-fact* for all the involved actors in the course: *students*, *teachers*, and *course coordinators* (Table 1). In real-time, the platform will provide the teachers with aggregated information regarding the learning-centered affective states of the students. This information will give the teachers the opportunity to respond in different ways such as changing the teaching style and/or intervene in the course content flow. Students are going to receive information regarding their own learning-centered states, which they can use to self-regulate and be active and engaged. Regarding the real-time feedback, the system will be designed in a way that optimizes its use while taking part in the educational activity. On a longer-term aspect, this aggregated information will be useful for the teachers and the course coordinators as it would play the role of an evidence-based course evaluation which can be used for future improvement of delivery style and course design from the side of the teacher and the course coordinator respectively.

4.2. Privacy

We acknowledge the privacy-sensitive nature of this study. To protect the privacy of students, and to prevent a possible misuse of the technology, e.g., using the obtained information to evaluate students, we design core privacy-preserving measures to shape our research around them. Firstly, all data collection and experimentation will be voluntary and with the informed consent of the participants. The ethical board will be consulted prior to all data collection phases. The training data will be collected anonymously with no possibility to link to individuals. Secondly, the designed system will keep sensitive individual data (e.g., video) on individuals' computers. We will use a virtual webcam that implements AI models and analyzes video data on client computers. This feature will also allow students to keep their camera off (use avatars or nothing at all) while still benefiting from the system. Only the processed and anonymized data (i.e., numerical representations of non-verbal cues) will be transferred, and the teacher will only be provided with information that is aggregated at classroom-level. Finally, this study solely aims at developing a method for improving the quality of online education, and not as a way of individual assessment of the students or the teachers. We are confident that this privacy-preserving design will not allow any misuse of the system.

4.3. Limitations

The source of the data in this study will be the participants' cameras, which results in two important limitations. First, we cannot observe the entire environment of a student, thus, it is not possible to differentiate whether the observed non-verbal cues of an individual student are the result of an event in the classroom or an off-task activity. Second, in the online classrooms, students are in control of their cameras and may refuse to turn them on even when the proposed privacy-preserving methods are in place. In that case, the proposed method is not applicable.

5. References

[1] Education: From disruption to recovery, 2021 URL: https://en.unesco.org/covid19/educationresponse.

[2] S. Dhawan, Online Learning: A Panacea in the Time of COVID-19 Crisis, Journal of Educational Technology Systems 49 (2020) 5–22. doi: 10.1177/0047239520934018.

[3] M. Alawamleh, L. M. Al-Twait, G. R. Al-Saht, The effect of online learning on communication between instructors and students during Covid-19 pandemic, Asian Education and Development Studies (2020). doi: 10.1108/AEDS-06-2020-0131.

[4] S. Gurung, Challenges faced by teachers in online teaching during Covid-19 pandemic, The online journal of distance education and e-Learning 9 (2021).

[5] S. D'Mello, A selective meta-analysis on the relative incidence of discrete affective states during learning with technology, Journal of Educational Psychology 105 (2013) 1082-1099. doi: 10.1037/a0032674.

[6] K. Bahreini, R. Nadolski, W. Westera, Towards multimodal emotion recognition in e-learning environments, Interactive Learning Environments, (2016) 590–605. doi: 10.1080/10494820.2014.908927.
[7] A. Lepp, J. E. Barkley, A. C. Karpinski, S. Singh, College Students' Multitasking Behavior in Online Versus Face-to-Face Courses, SAGE Open 9 (2019), doi: 10.1177/2158244018824505.
[8] C. Jewitt, J. Bezemer, K. O'Halloran, Introducing multimodality, 1st. ed., Routledge, London, 2016. doi: 10.4324/9781315638027.
[9] APA Dictionary of Phycology, 2020. URL: https://dictionary.apa.org/nonverbal-communication.
[10] N. Kock, Media naturalness theory: human evolution and behaviour towards electronic communication technologies, in: S Craig Roberts, Applied evolutionary psychology, Oxford University Press Inc., New York, 2012, pp. 381-398. doi: 10.1093/acprof:oso/9780199586073.001.0001.
[11] O. Weiser, I. Blau, Y. Eshet-Alkalai, How do medium naturalness, teaching-learning interactions and Students' personality traits affect participation in synchronous E-learning?, Internet and Higher Education 37 (2018) 40–51. doi: 10.1016/j.iheduc.2018.01.001.
[12] P. Ekman, An Argument for Basic Emotions, Cognition and Emotion 6 (1992) 169–200. doi: 10.1080/02699939208411068.
[13] R. Reisenzein, M. Studtmann, G. Horstmann, Coherence between emotion and facial expression: Evidence from laboratory experiments, Emotion Review 5 (2013) 16–23. doi: 10.1177/1754073912457228.
[14] M. Wegrzyn, M. Vogt, B. Kireclioglu, J. Schneider, J. Kissler, Mapping the emotional face. How individual face parts contribute to successful emotion recognition, PLoS ONE 12, (2017) doi: 10.1371/journal.pone.0177239.
[15] P. Tarnowski, M. Kołodziej, A. Majkowski, R. J. Rak, Emotion recognition using facial expressions, Procedia Computer Science 108 (2017) 1175–1184. doi: 10.1016/j.procs.2017.05.025.
[16] M. A. A. Dewan, M. Murshed, F. Lin, Engagement detection in online learning: a review, Smart Learning Environments 6 (2019). doi: 10.1186/s40561-018-0080-z.
[17] D. Umnia Soraya, K. Candra Kirana, S. Wibawanto, H. Wahyu Herwanto, C. Wijaya Kristanto, Non-Verbal Communication Behavior of Learners on Online-based Learning, in: Proceedings of the 2nd International Conference on Vocational Education and Training (ICOVET 2018), 2019, pp. 4-6. doi: 10.2991/icovet-18.2019.2.
[18] M. Sharma, D. Ahmetovic, L. A. Jeni, K. M. Kitani, Recognizing Visual Signatures of Spontaneous Head Gestures, in: 2018 IEEE Winter Conference on Applications of Computer Vision (WACV), 2018, pp. 400-408. doi: 10.1109/WACV.2018.00050.
[19] Nigel Bosch, Sidney D'Mello, Ryan Baker, Jaclyn Ocumpaugh, Valerie Shute, Matthew Ventura, Lubin Wang, Weinan Zhao, Automatic detection of learning-centered affective states in the wild, in: Proceedings of the 20th International Conference on Intelligent User Interfaces (IUI '15), Association for Computing Machinery, New York, 2015, pp. 379–388. doi: 10.1145/2678025.2701397.
[20] T. S. Ashwin, R. M. R. Guddeti, Affective database for e-learning and classroom environments using Indian students' faces, hand gestures and body postures, Future Generation Computer Systems 108 (2020), 334–348. doi: 10.1016/j.future.2020.02.075.
[21] J. Whitehill, Z. Serpell, Y. C. Lin, A. Foster, J. R. Movellan, The faces of engagement: Automatic recognition of student engagement from facial expressions, IEEE Transactions on Affective Computing 5, (2014) 86–98. doi: 10.1109/TAFFC.2014.2316163.
[22] L. B. Krithika, G. G. Lakshmi Priya, Student Emotion Recognition System (SERS) for e-learning Improvement Based on Learner Concentration Metric, in Procedia Computer Science 85

(2016) 767–776. doi: 10.1016/j.procs.2016.05.264.

[23] K. Holstein, B. M. McLaren, V. Aleven, Co-designing a real-time classroom orchestration tool to support teacher–ai complementarity, Journal of Learning Analytics 6 (2019) 27–52. doi: 10.18608/jla.2019.62.3.

[24] M. D. Wilkinson, M. Dumontier, I. J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J. W. Boiten, L. O. B. da Silva Santos, P. E. Bourne, J. Bouwman, A. J. Brookes, T. Clark, M. Crosas, I. Dillo, O. Dumon, S. C. Edmunds, C. T. A. Evelo, R. Finkers, A. N. González-Beltrán, A. J. G. Gray, P. Groth, C. A. Goble, J. S. Grethe, J. Heringa, P. A. C. 't Hoen, R. W. W. Hooft, T. Kuhn, R. G. Kok, J. N. Kok, S. J. Lusher, M. E. Martone, A. Mons, A. Laerte Packer, B. Persson, P. Rocca-Serra, M. Roos, R. C. van Schaik, S. Sansone, E. A. Schultes, T. Sengstag, T. Slater, G. O. Strawn, M. A. Swertz, M. Thompson, J. van der Lei, E. M. van Mulligen, J. Velterop, A. Waagmeester, P. Wittenburg, K. Wolstencroft, J. Zhao, B. Mons, The FAIR Guiding Principles for scientific data management and stewardship, Scientific Data 3 (2016). doi: 10.1038/sdata.2016.18.

Detecting emotions in a learning environment: a multimodal exploration

Sharanya Lal, Tessa H.S. Eysink, Hannie A.H. Gijlers, Willem B. Verwey and Bernard P.Veldkamp

University of Twente, Drienerlolaan 5, Enschede, 7522 NB, The Netherlands

Abstract

Learner-emotions are intrinsically linked with learning experiences and academic outcomes. Therefore, intelligent learning environments need to be emotion-aware to bring learners to their zone of proximal development. In this paper, we describe the first steps towards such a system. In this study, we manipulated task difficulty with the aim of detecting the physiological indicators of accompanying emotions, namely boredom/anger (during an easy task), enjoyment (during a moderately challenged task) and frustration/boredom (during a difficult task). Twenty-one adults (13 females and 8 males, Mage = 24.1 years) participated in a repeated- measures quasi-experimental set-up. Data were collected via Empatica E4 wristbands and self-reports. Results indicate that varying task difficulty may be associated with changes in skin temperature, phasic and tonic skin conductance, and heart rate. Findings encourage further exploration and thoughts on study design are discussed.

Keywords [1]

psychophysiology, wearables in education, affective computing, emotion detection

1. Introduction and background

1.1. Emotions in learning

Emotions play a significant role in learning and this is evidenced by the growing body of work on the interaction of learner emotions, well-being, and learning outcomes [1], [2], [3], [4], [5]. For example, [5] found that the induction of positive emotions in learners resulted in higher learning transfer, greater mental engagement and lower levels of reported task difficulty. In another study, [6] found that positive emotions (namely enjoyment and pride) predicted high learning achievements while the opposite was true for negative emotions (namely anger, anxiety, shame, boredom and hopelessness). Therefore, to optimise learning experiences and outcomes, it is essential that one takes learner emotions into account. In today's era of digital learning, this calls for intelligent learning systems that can detect learners' emotions to provide optimally adjusted support.

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: s.lal@utwente.nl (A. 1); t.h.s.eysink@utwente.nl (A. 2); a.h.gijlers@utwente.nl (A. 3); w.b.verwey@utwente.nl (A. 4); b.p.veldkamp@utwente.nl (A. 5)
ORCID: 0000-0002-6228-8850 (A. 1); 0000-0001-5820-4469 (A. 2); 0000-0003-2406-6541 (A. 3); 0000-0003-3994-8854 (A. 4); 0000-0003-3543-2164 (A. 5)

1.2. Theoretical perspectives

In their meta-study that showed strong correlations between emotional, cognitive and learning processes in e-learning environments, [7] suggest fostering optimal levels of subjective control (i.e., a learner's appraisal of how much control over a task they have) and value (i.e., the value a learner places on a task). Their results align with and suggestions rely heavily on Pekrun's [4] Control-Value theory that states that the subjective appraisals of control and value are central to emotions related to learning. For example, if the learner sees positive value in a task and has high control of actions, they experience enjoyment. On the other hand, if they see no value in the task, they feel bored irrespective of whether they have high or low control. Similarly, if learners find themselves unable to control an activity, they experience frustration irrespective of the value they placed on the same. Pekrun's [4] activity related emotions draw on Csikszentmihalyi's [1] seminal work on 'flow' – a state of extreme concentration, when someone is so engaged in the task at hand that they forget the passage of time. Flow theory suggests that learners in 'flow' experience enjoyment and happiness and that this is achieved when one not only has a clear goal, a sense of purpose and immediate feedback, but also a balance of challenge and skill (with challenge and skill level being just above the average for the person) [1], [8]. This in turn shares similarities with one of the most significant concepts in learner centric education – the Zone of Proximal Development (ZPD) [9], which posits that learning is optimal when a task is just out of the learner's reach and they have available the assistance of a more skilled/knowledgeable person. Taking cue from this, in this study, we look at emotions in light of learner's perceptions of task difficulty, challenge to skill balance, absorption in a task and control-value appraisals.

1.3. Detecting emotions

Emotion detection has traditionally been done through learner reported data [10]. Such an approach has several limitations including the subjective nature of self-reports and the likely temporal mismatch between when an emotional state has occurred and data are collected [11]. The latter could result in the collection of data for another moment in time or even inaccuracies when recalling past experiences. Consequently, there is much interest in alternate approaches to emotion detection that can provide objective, time-specific and reliable data. One approach that is notably gaining traction is the use of physiological measures to understand underlying psychological processes. For example, [12] found that emotional valence (i.e., the extent to which an emotion is negative or positive) was positively related to blood volume pulse (i.e., a measure of the changes in blood volume flowing through one's arteries and capillaries). Skin conductance (i.e., skin's property of conducting electricity) has been found to reflect stress during a task [13], and emotional arousal [14]. In recent educational research specifically, [15] studied adolescent girls learning in maker-spaces and found that skin conductance was positively related to engagement. In another study, [16] measured average student heart rates (i.e., the number of heart beats per minute) during medical school lectures and found a steady decline from the start to the end of a lecture. They also found that heart rate significantly increased during periods of student interaction such as group-based problem solving. More recently, [17] in a study involving 67 students solving statistical exercises of varying difficulty found that heart rate and skin temperature were significantly related to self-reported cognitive load and skin temperature specifically to task performance. Studies like these suggest that these measures are useful indicators of challenge to skill balance, perceived task difficulty and task absorption and can therefore offer a glimpse into learner emotions. Physiological signals that can now be assessed with portable devices give us access to vast amounts of uninterrupted, time-specific and objective data points, thus bringing us closer to understanding a learner's emotional state in real-time. However, research is still at a nascent stage and there is value in advancing the body of literature on the same (e.g., [18], [19], [20]).

2. Research aims of present study

The present study is the first step in our research project that is geared towards developing an intelligent learning system that adapts to a learner's emotions so as to bring them to their ZPD. Therefore, this paper focuses on emotion detection. To this end, a repeated-measures quasi- experimental design was adopted wherein physiological data in combination with self- reported measures were used to detect emotional states. The physiological signals investigated in the study were skin conductance, skin temperature, blood volume pulse and heart rate. Emotional states were elicited primarily through the manipulation of task difficulty in a digital learning environment designed to teach programming skills. This manipulation (see Methods) was done with the expectation that it would lead to differences in learners' perceptions of challenge to skill balance, task absorption and therefore emotions. Drawing on the ideas of Csikszentmihalyi [1] and Pekrun [4] and past studies on psychophysiological measures,several conjectures were made:

1. For the task that was too easy, learners would perceive a mismatch between challenge and skills and have lowabsorption in task. Based on their appraisal of control over and value of the task, they would experience either boredom (no value, high control) or anger (negative value, high control). Boredom being a deactivating emotion (i.e., one that is associated with low arousal) would be associated with low skin conductance and heart rate. Anger on the other hand being an activating emotion (i.e., one that is associated with high arousal) would be associated with high skin conductance and heart rate.
2. For the task that was too difficult, the expectation was that learners would perceive a mismatch between challenge and skills and have low absorption in task. Based on control and value appraisal of the task, they would either experience frustration (positive/negative value, low control) or boredom (no value, low control). Unlike boredom, frustration being an activating emotion would be associated with high skin conductance and heart rate.
3. For the task that was neither too difficult nor too easy, it was expected that learners would perceive a balance between the challenge and their skills and have high task absorption. An appraisal of high control and high value of the task would be associated with a positive emotional state (i.e., enjoyment). Enjoyment being an activating emotion would be associated with high skin conductance and heart rate.We also expected blood volume pulse to be an indicator of emotional valence [12] and skin temperature to be high during the difficult task [17].

Emotional states were also elicited through a sample taken from the Open Affective Standardised Image Set (OASIS) [21] (described in Methods). The hypothesis was thatthe valence and arousal associated with the different images would be reflected in the physiological signals. Therefore, these could act as reference points when interpreting emotions during the programming tasks.

Thus, this study aimed to detect psychophysiological indicators (if any) of learner emotions associated with tasks of varying difficulty.

3. Methods

3.1. Participants

Participants consisted of 21 (13 females and 8 males, 19-32 years old, M_{age} = 24.14 years) university students and working professionals based in the Netherlands. The sample consisted of persons of 6 nationalities and different educational levels (11 bachelor students, 1 bachelor's degree holder, 8master's degree holders and 1 PhD student). All participants had at least working knowledge of English and basic computer skills. Participation was voluntary and active consent had been received from all participants before the start of theexperiment.

3.2. Materials

3.2.1. Primary stimuli set – programming tasks

In the learning environment [22], participants programmed instructions by joining blocks of code to control a red 'robot' (see Figure 1). The goal was to make the robot reach the end of its path by coding its trajectory. Paths could be 5-, 10- or 15-step, each requiring a longer or more sophisticated piece of code than the previous. The environment also had a free-play 'Sandbox' mode, in which participants were free to explore the environment in any way they wanted – there was no specific aim to this activity. Three tasks of varying difficulty were designed within the learning environment. The moderately challenging task was to complete a 5-, 10- and 15-step path (see Figure 2) within 10 minutes. The easy task was to do a 5-step path over and over again for 10 minutes. The difficult task was to 'decipher the aim and rules of the Sandbox' and 'complete it successfully' in 10 minutes. This was considered 'difficult' because the Sandbox mode does not actually have a tangible goal or rules, thus making the task a wild goose chase (however, participants were not aware of this fact). User responses during pilot testing of the environment and tasks concurred with these expectations.

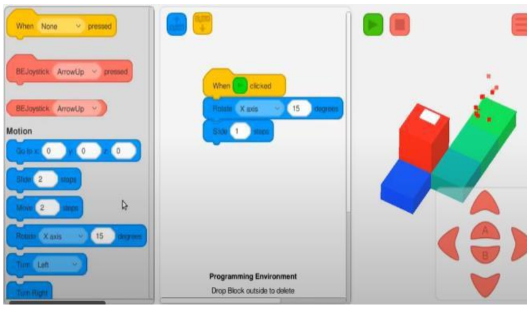

Figure 1: In the digital learning environment, participants selected blocks of code (left pane), edited and joined them to form a piece of code (center pane) that would move the red robot to the end of its path (right pane)

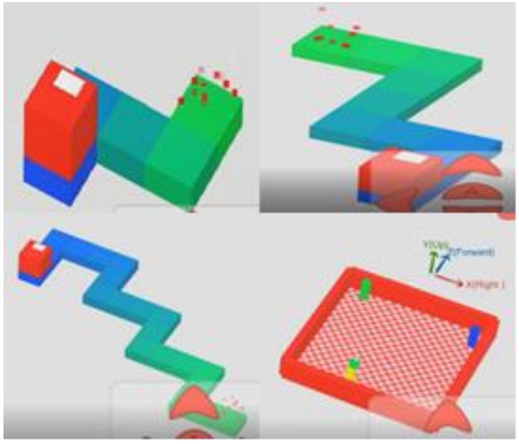

Figure 2: In the learning environment, one could either code to make the red robot reach the end of its 5- (Top-Left), 10- (Top-Right) or 15-step (Bottom-Left) path, or explore freely in the Sandbox mode (Bottom-Right)

3.2.2. Baseline-measurement stimulus

A video with the instructions, "Sit still and relax" was displayed for 5 minutes. At the 4 m 50s mark, an audio signal indicated the end of the rest period. At this point, the phrase "I feel: " followed by a smiley meter (described in a subsequent sub-section) appeared on the screen for 10 seconds.

3.2.3. Secondary stimuli set – images

A set of 35 500x400 pixel images – 13 positive (for example, a puppy in a teacup), 10 negative (for example, garbage) and 12 neutral (for example, a tiled roof) were sampled from OASIS [21]. The value given to these images was based on participant-reported valence in the original study. While sampling, graphic and sexually explicit images were excluded. The images were presented one after the other with intermittent 5 s pauses wherein a blank screen was inserted. Each image was displayed for 10 seconds. On the 6th second, a smiley meter (described in a subsequent paragraph) along with the phrase "This photo makes me feel…" appeared below the image and stayed visible till the end of the 10th second.

3.2.4. Hardware and software set up

Physiological data were collected using the biosensing wristband E4. The E4 makes use of an electrodermal activity sensor that measures sympathetic nervous system arousal via stainless steel electrodes that are placed on the ventral wrist. This arousal is quantified in terms of skin conductance which is measured in microSiemens (µS) and sampled at 4 Hz (i.e., 4 readings per second). Skin temperature was collected in degree Celsius (°C) via the E4's infrared thermopile sensor at a sampling frequency of 4 Hz. Blood volume pulse was collected from the E4's photoplethysmography (PPG) sensor placed on the dorsal wrist and was sampled at 64 Hz. Heart rate (calculated per 10 s) was derived from blood volume pulse. In addition to this, acceleration data (indicating movement) from the E4's accelerometerwere collected at 32 Hz. All data were streamed to Empatica's cloud-based repository via an android application set up on a mobile phone which in turn was connected via Bluetooth to the E4. The internal clock of the E4 was synchronised with that of the computer on which the stimuli were loaded. A screen recorder was set up on the computer so as to capture timestamps of the different stimuli and digital behaviour during the programming tasks. A handheld timer was used to facilitate and keep trackof the different activities in the study.

3.2.5. Self-reports

Self-reported data were collected using several tools:

Smiley meter: A five point smiley meter [23] was used to collect participants' perception of different stimuli during the study. Participants were expected to reflect on how the stimulus (a programming task, a baseline activity or an image) made them feel and point to the smiley that best represented their emotional state. The scale was used unmarked to avoid putting specific affect-related words into the participant's head.

Short flow scale (SFS) and task difficulty scale: A 20-item short flow scale [24] was used asa self-report of experiences during the three programming tasks. The SFS has 2 sub-scales, 'Challenge to skill balance' (Chal2Skill) (11 items) and 'Task Absorption' (Task_Absorption) (9 items) [24]. Since the twostatements in the scale , "It was boring for me" and "My attention was not engrossed at all by the activity" were negatively framed, they were recoded. Testing for reliability, we foundCronbach's α = .92, α = .79 and α = .91 of the SFS for the moderately challenging, easy and difficult task respectively. Reliability tests were also performed for each subscale 'challenge to skill balance' ('Chal2Skill') and 'task absorption' ('Task_Absorption'). We found that the sub-scales Chal2Skill and Task_Absorption had a) Cronbach's α = .95 and α = .74 respectively, for the moderately challenging task, b) α = .91 and α = .93 respectively, for the easy task, and c) α = .88 and α = .90 respectively, for the difficult task. Consequently, new variables valued as the mean of each subscale were computed to be used for further analyses. It is important to note that lowand high Chal2Skill ratings denote an imbalanceof challenge and skill (i.e. a task is too difficult or a task is too easy, respectively) and a moderate Chal2Skill rating denotes a balance of challenge and skill. Another self-report measure used after the programming tasks was a one- item scale on perceived task difficulty(henceforth referred to as the Task_Difficulty scale). The scale consisted of the following item – 'Was this task 1) Too easy 2) Easy 3) Just right 4) Difficult 5) Very difficult?'

Interview: An audio-recorded face-to-face semi- structured interview was conducted at the end of the study to glean participants' experiences during the experiment. Participants were asked how they were feeling at the start and end of the study, if they could describe their experiences during the different programming tasks and baselines, and their rationale for selecting a particular smiley on corresponding smiley meters.

3.3. Procedure

This study took place during the Covid-19 pandemic. Consequently, participants received hygiene and safety guidelines by e-mail and the experimental space and all equipment were sanitized before each use. On the day of the study, participants were individually seated in a closed lab space set up to minimize external distractions. Demographic data of participants namely age, sex, nationality, handedness, prior knowledge in programming and educational level were collected. Participants then received a general outline of the experimental set-up, procedure, tools and expected code of conduct. Once ready, they were fitted with the Empatica E4 on their non-dominant hand to mitigate the effects of hand movements, making sure that the wristband's sensors made complete skin contact and the electrodes for skin conductance detection were in line with the gap between the middle and ring finger. The E4 was then switched on, and readings were checked to see that a stable connection had been established. Participants then faced a computer screen with their non-dominant hand either on their lap or on the table. Participants first watched an instructional video outlining the components of the learning environment and how to navigate it. They were then guided by the baseline video during which they sat still and could either look at the computer screen orthe white wall behind it, or keep their eyes closed. Then participants proceeded to do the three programming tasks one after the other. The completion of the tasks was followed by another baseline reading, then a viewing of the images and a third and final baseline reading. After each baseline, programming task and image, participants indicated their emotional state on the smiley meter. Thus for each participant, a total of 41 smiley meter ratings were collected. Meanwhile, the researcher kept time, took notes and checked that the wristband was collecting a continuous stream of data. Participants then filled three copies of the SFS and Task_Difficulty scale, once for each programming task, were interviewed and finally debriefed about the purpose of the study. Figure 3 shows the experimental procedure.

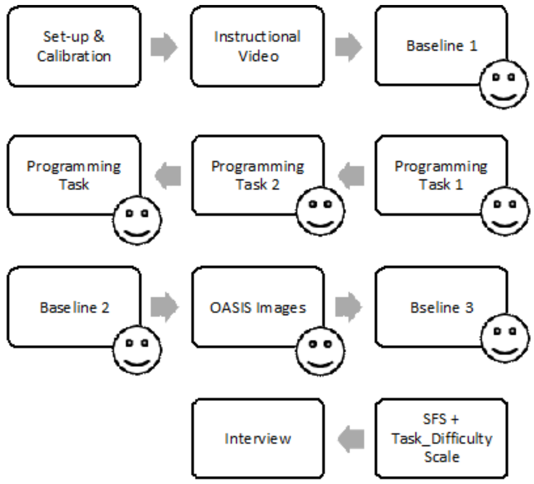

Figure 3: Study procedure

3.4. Data pre-processing

Blood volume pulse, heart rate, skin conductance and skin temperature readings were obtained as separate files. These were combined using a Python program that took the earliest and latest time stamps and interpolated all readings between the two. This involved bringing all data capturing times to a 0.25 second temporal resolution (in keeping with the 4 Hz sampling rate of the electrodermal activity sensor). Timestamps for various user actions and events (i.e., start and end of a stimulus) were obtained from screen recordings and added to these data. These were used to determine the duration of time windows to be analysed. Baselines were computed as the start of the baseline video to the reading just before the appearance of the smiley meter. The duration of an image stimulus was coded as the moment the image was displayed to the moment just before the appearance of the smiley meter. Task duration was 10 minutes unless a participant took less time to complete a task. All continuous physiological readings falling within a time window were averaged. These were then standardised by subtracting from them the average of all the baseline readings. Further analyses were performed using these standardised values.

Skin conductance was pre-processed using the MATLAB (The MathWorks, Inc., Natick, MA, U.S.A.) software package 'Ledalab' (version 3.4.9 http://www.ledalab.de). Signal pre-processing included decomposition to its two components, phasic skin conductance (rapidly changing signal) and tonic skin conductance level (slow-moving signal), using the continuous decomposition analysis method [25] and feature extraction. Feature extraction was done using a threshold of 0. 01 µS. Phasic signal features that were extracted were namely onset and amplitude of non-specific significant skin conductance responses (nSCRs). These were used to compute nSCR frequency (nSCR/min) for each programming task. Baseline nSCR frequency was computed as the average of all three baselines. Taking cue from Pijeira-Díaz et al. (2018), phasic skin conductance was computed as a categorical variable with 3 values: 0 (low nSCR frequency – 0 to 3 SCR/min), 1 or (medium nSCR frequency – 4 to 20 nSCR/min) and 2 (high nSCR frequency – 21 and above nSCR/min). Tonic skin conductance data was extracted as a continuous variable.

4. Results

To answer the exploratory question of whether we could detect psychophysiological indicators (if any) of learner emotions associated with tasks of varying difficulty, we made comparisons across the three tasks and deviations from the baseline. We used linear mixed models while controlling for acceleration and demographic data. Pairwise comparisons were computed having applied Bonferroni correction. Across tasks, we found a significant variation in skin conductance [$F(3, 60) = 15.09$, $p = 0.00$] , heart rate [$F(3, 60) = 9.61$, $p = 0.00$] and temperature [$F(3, 60) = 3.13$, $p = 0.03$]. Please refer to Figures 4, 5 and 6 for more details.

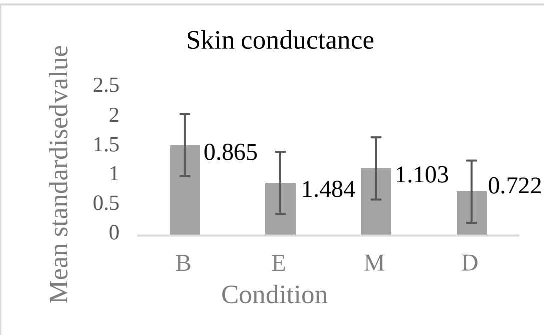

Figure 4: SC at baseline (B) was significantly higher than that during the easy (E) [mean difference = 0.62, p = 0.00], moderately challenging (M) [mean difference = 0.38, p = 0.02] and difficult (D) tasks [mean difference = 0.76, p = 0.00]. SC during the moderately challenging task (M) was significantly higher than that during the difficult (D) task [mean difference = 0.38, p = 0.02].

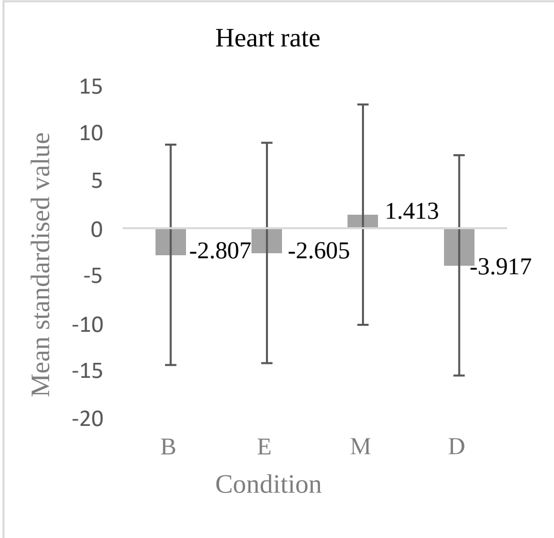

Figure 5: Heart rate during the moderately challenging task (M) was significantly greater than that during the baseline (B) [mean difference = 4.22, p = 0.00], easy (E) [mean difference = 4.02, p = 0.00] and difficult (D) tasks [mean difference = 5.33, p = 0.00].

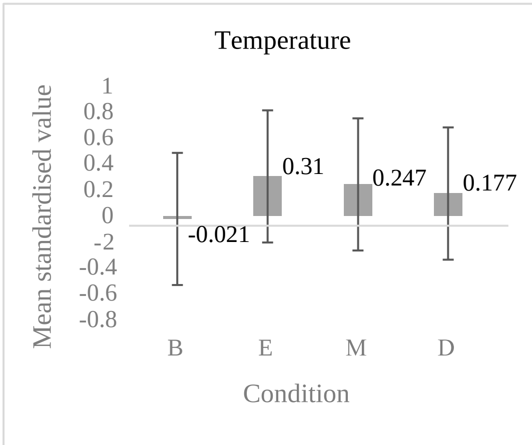

Figure 6: Temperature during the easy (E) task was significantly higher than that during the baseline (B), [mean difference = 0.33, p = 0.03]. No significant changes during the moderately challenging (M) and difficult (D) tasks were observed.

Results indicated no significant changes in blood volume, $F(3, 60) = 1.20$, $p = 0.32$ and tonic skin conductance, $F(3, 66) = 1.46$, $p = 0.23$.

Relationships between physiological data and appraisals of challenge to skill balance, task difficulty and task absorption were explored. To do this, demographic data were included as fixed factors and participant was a random factor in the linear mixed model. We found no effect of Chal2Skill (F(1, 38.04) = 0.79, p = 0.38), Task_Absorption (F(1, 37.61) = 0.06, p = 0.81) and Task_Difficulty (F(4, 36.06) = 0.10, p = 0.98) on phasic skin conductance. We also found no effect of Chal2Skill (F(1, 33.69) = 1.97, p = 0.17), Task_Absorption F(1, 33.58) = 0.46, p = 0.50) and Task_Difficulty (F(4, 33.35) = 0.96, p = 0.44) on heart rate. No significant effect of Chal2Skill (F(1, 34.88) = 1.45, p = 0.24), Task_Absorption (F(1, 34.61) = 1.45, p = 0.24) and Task_Difficulty (F(4, 33.96) = 0.93, p = 0.46) was found on blood volume pulse. Chal2Skill (F(1, 38.60) = 1.29, p = 0.26), Task_Absorption (F(1, 38.22) = 0.80, p = 0.38) and Task_Difficulty (F(4, 36.37) = 2.09, p = 0.10) had no significant effects on temperature. Chal2Skill was found to have a positive effect on tonic skin conductance (β = 0.43, t(36.96) = 2.93, p = 0.00, 95% CI [0.13, 0.73] and Task_Absorption was found to have a negative effect (β = -0.37, t(37.38) = -3.56, p = 0.00, 95% CI [-0.59, -0.16]). There are some indications that Task_Difficulty ratings negatively affect tonic skin conductance: For Task_Difficulty = 1, β = -2.27, t(34.67) = -4.33, p = 0.00, 95% CI [-3.34, -1.21], for Task_Difficulty = 2, β = -1.20, t(33.77) = -2.48, p = 0.02, 95% CI [- 2.19, -0.22], for Task_Difficulty = 3, β = -0.88, t(34.70) = -2.09, p = 0.04, 95% CI [-1.74, -0.03] and for Task_Difficulty = 4, β = 0.036, t(34.91) = 0.12, p = 0.90, 95% CI [-0.56, 0.63].

Next, to examine whether the valence of (OASIS image-induced) emotions would be reflected in physiological data, relationships between the latter and smiley meter ratings for images were analysed. We found no significant relation between smiley meter ratings and tonic skin conductance levels [F(4, 677.72) = 1.63 , p = 0.17] , blood volume pulse [F(4, 654.02) = 0.97 , p = 0.42], heart rate [F(4, 683.29) = 1.66 , p = 0.16] and skin temperature [F(4, 676.20) = 1.37 , p = 0.24]. Feature extraction from phasic skin conductance data corresponding to the image stimuli resulted in no significant SCRs for practically the whole dataset (except 1 to 2 images of few participants).

Finally, we also evaluated the stimuli, i.e., examined whether participants perceived the programming tasks as they were intended to be (namely, task 1 – moderately challenging and positive-emotion inducing, task 2 – too easy, negative-emotion inducing, and task 3 – too difficult, negative-emotion inducing). We used linear mixed models while controlling for demographic data. Results indicated significant differences in Chal2Skill ratings [F(2, 40) = 43.59, p = 0.00]. The average Chal2Skill rating for the moderately challenging task exceeded that of the difficult task (mean difference = 1.43, p = 0.00), while that of the easy task was greater than that of the moderately challenging (mean difference = 0.76, p = 0.01) and difficult task (mean difference = 2.20, p = 0.00). We found significant differences in Task_Difficulty ratings [F(2, 39) = 40.97, p = 0.00]. As expected, Task_Difficulty ratings for the difficult task were greater than those of the moderately challenging task (mean difference = 1.86 , p = 0.00) and easy task (mean difference = 2.60, p = 0.00), while ratings for the moderately challenging task were higher than those for the easy task (mean difference = 0.75, p = 0.05). No significant differences in Task_Absorption ratings were found [F(2, 40) = 2.15, p = 0.13]. We also found no significant differences in smiley meter ratings for the different tasks, F(2,46) = 1.14, p = 0.33. This is corroborated by the interviews in which several participants exhibit recall bias at the time of responding to the smiley meters. For example, one participant provided a low smiley meter rating despite having enjoyed the task simply because they felt disappointed at not being able to complete it on time. In another case, a participant displayed agitation through most of the task period but gave a high rating because they managed to understand the task towards the end. Consequently, smiley meter ratings for the tasks were not included in any other analyses. During the interviews, some words used to describe experiences during the moderately challenging task were “confused”, “challenging”, “enjoyable” and “fun”. Some participants (n = 5) described feeling slightly stressed or frustrated when they could not find a solution at the beginning, but feeling better afterwards. Some (n = 4) displayed disappointment at not being able to complete the task. Talking about the easy task, most participants (n = 13) mentioned its repetitive nature or described being bored at some point during the task. While describing their experience during the difficult task, most participants (n = 11) mentioned frustration, annoyance, a sense of hopelessness or incompetence.

5. Discussion

In this study, we attempted to detect physiological indicators of learning related emotions by using multimodal data from a biosensing wristband and self-reports. To this end, we presented participants with an easy, moderately challenging and difficult task with the expectation that these would be associated with different emotions. It was expected that during the easy and difficult tasks, participants would experience negative emotions (boredom/frustration/anger). This negative emotional state would be associated with a combination of low blood volume pulse and either low skin conductance and heart rate, or high skin conductance and low heart rate. We also expected that during the moderately challengingtask, participants would experience a positive emotional state (i.e., enjoyment), which in turn would be associated with high blood volume pulse, skin conductance and heart rate. Results show that participants in general had lower phasic skin conductance and heart rate during the difficult task as compared to the moderately challenging task. In fact, heart rate during the moderately challenging task was also higher than that during baseline and the easy task. On the other hand, no significant differences in blood volume pulse were found. Thefindings of high heart rate and phasic skin conductance during the moderately challenging task align with our expectation of indicators of enjoyment. Similarly, low phasic skin conductance, tonic skin conductance and heart rate during the difficult task could indicate boredom. While we did not see high skin temperatures during the difficult task as expected, indications of high skin temperature and tonic skin conductance levels during the easy task could indicate anger [26], [27].These indications of enjoyment, boredom and anger also align with our expectations based on the control-value theory [6]. However, a comparison with self-reports and certain limitations of the study (discussed below) suggest that more evidence is required to ascertain whether all these physiological changes are indeed due to the emotional stimuli.

The biggest limitations of this study are the fixed order of the programming tasks and a lack of sufficient evidence to ascertain clear relationships between all the physiological signals and self- reports. Therefore, we cannot write off order-effects and there is a great likelihood that the changes in physiological signals are simply due to the passage of time. Also, there is the issue of obtaining clear self-reports on emotions. In this study, data fromthe smiley meters did not add value to the analysis. The decision to use a smiley meter was to ensure that we did not put words into participants' heads. However, this resulted in not having direct measures of learner emotions and having to make inferences based only on learner appraisals of task difficulty, challenge to skill balance and task absorption. We also gathered that the 10 minute intervals between smiley meter ratings on the programming tasks were likely too long as several participants displayed recall bias. Since these limitations warrant further research, in our next study, we will tweak our design to ensure increased reliability of our findings. Firstly, we plan to randomise the order of tasks for each participant. And secondly, we will collect regular and intermittent reports during the task (for example, every 3 to4 minutes) on a more sophisticated scale such as the Affect Grid [28]or Self-Assessment Manikin [29].

The use of physiological measures of emotion detection has important theoretical and practical implications. As mentioned earlier, the vast majority of studies in learner emotion have utilized self-reported data [10]. These include the building of significant educational theories such as [6]. An approach utilizing multimodal data including physiological data (such as whatwe do in this study) opens up the possibility to test such theories in a more robust manner and advance our knowledge base on learner psychology. Additionally, such studies take us closer towards realizing intelligent systems that can detect and therefore cater to the emotions of learners. The results of the present study thus contribute towards the field of emotions in learning.

6. Conclusion

In the present study, we found indications that certain learner emotions related to different task difficulties may possibly be characterised by a combination of phasic and tonic skin conductance, heart rate, and skin temperature. Such a psychophysiological approach to emotion detection can open the doors to real- time adaptive support that can bring learners to their zone of proximal development and consequently greatly improve learning outcomes. Therefore, though the results of the present study are far from definitive, we see value in advancing research in this area. Our next steps include a) furthering our exploration of signals collected from the E4 after including design changes derived from this study, b) exploring other nonintrusive measures of learner engagement such as camera based eye tracking and screen activity, c) developing a multimodal system of emotion detection, d) prototyping an adaptive system based on affective feedback.

7. Acknowledgements

This study was funded by the BMS Signature PhD grant at the University of Twente and made possible with the technical assistance of the university's BMSLab. We would like to thank André Bester and Lucia M. Rabago Mayer for the Python code, setting up the Unity platform and other technical guidance. We would also like to thank Johannes Steinrücke for his guidance on statistical methods, especially linear mixed models.

8. References

[1] B. Mihaly Csikszentmihalyi, Flow: The Psychology of Optimal Experience, Harper & Row, New York, 1990.

[2] Kort, Barry, Rob Reilly and Rosalind W. Picard, An affective model of interplay between emotions and learning: engineering educational pedagogy-building a learning companion, in*:* Proceedings IEEE International Conference on Advanced Learning Technologies, 2001, pp 43-46. doi: 10.1109/ICALT.2001.943837

[3] R. E. Mayer, Searching for the role of emotions in e-learning, Learn. Instr. 70 (2019). doi: 10.1016/j.learninstruc.2019.05.010.

[4] R. Pekrun, The control-value theory of achievement emotions: assumptions, corollaries, and implications for educational research and practice, Educ. Psychol. Rev. 18 (2006), pp. 315–341. doi: 10.1007/s10648-006-9029-9.

[5] E. R. Um, J. L. Plass, E. O. Hayward, B. D. Homer, Emotional design in multimedia learning, J. Educ. Psychol. 104 (2012), pp. 485–498. doi: 10.1037/a0026609.

[6] R. Pekrun, S. Lichtenfeld, H. W. Marsh, K. Murayama, T. Goetz, Achievement Emotions and Academic Performance: Longitudinal Models of Reciprocal Effects, Child Dev. 88 (2017), pp. 1653–1670. doi: 10.1111/cdev.12704.

[7] K. Loderer, R. Pekrun, J. C. Lester, Beyond cold technology: A systematic review and meta-analysis on emotions in technology-based learning environments, Learn. Instr. 70 (2020). doi: 10.1016/j.learninstruc.2018.08.002.

[8] K. S. Beard, Theoretically Speaking: An Interview with Mihaly Csikszentmihalyi on Flow Theory Development and Its Usefulness in Addressing Contemporary Challenges in Education, Educ. Psychol. Rev. 27 (2015). doi: 10.1007/s10648- 014-9291-1.

[9] L.S. Vygotsky, Mind in society: The development of higher psychological processes, Harvard University Press, Massachusetts, 1978.

[10] C. H. Wu, Y. M. Huang, J. P. Hwang, Review of affective computing in education/learning: Trends and challenges, Br. J. Educ. Technol. 47 (2016). doi: 10.1111/bjet.12324.

[11] E. Yadegaridehkordi, N. F. B. M. Noor, M. N. Bin Ayub, H. B. Affal, N. B. Hussin, Affective computing in education: A systematic review and

future research, Comput. Educ. 142 (2019). doi: 10.1016/j.compedu.2019.103649.

[12] E. H. Jang, M. S. Park, B. J. Park, S. H. Kim, M. A. Chung, J. H. Sohn, Relationship between affective dimensions and physiological responses induced by emotional stimuli: Base on affective dimensions: Arousal, valence, intensity and approach, in: Proceedings of PhyCS 2014 - Proc. Int. Conf. Physiol. Comput. Syst., 2014, pp. 254–259. doi: 10.5220/0004728302540259.

[13] Brouwer, A., Van Beurden, M., Nijboer, L., Derikx, L., Binsch, O., Gjaltema, C., Noordzij, M., A comparison of different Electrodermal variables in response to an acute social stressor, Symbiotic Interaction 7 (2018). doi: https://doi.org/10.1007/978-3-319-91593-7_2.

[14] M. Jindrová, M. Kocourek, P. Telenský, Skin conductance rise time and amplitude discern between different degrees of emotional arousal induced by affective pictures presented on a computer screen, bioRxiv (2020). doi: 10.1101/2020.05.12.090829.

[15] V. R. Lee, L. Fischback, R. Cain, A wearables-based approach to detect and identify momentary engagement in afterschool Makerspace programs, Contemp. Educ. Psychol. 59 (2019). doi: 10.1016/j.cedpsych.2019.101789.

[16] D. K. Darnell, P. A. Krieg, Student engagement, assessed using heart rate, shows no reset following active learning sessions in lectures, PLoS One 14 (2019). doi: 10.1371/journal.pone.0225709.

[17] C. Larmuseau, J. Cornelis, L. Lancieri, P. Desmet, F. Depaepe, Multimodal learning analytics to investigate cognitive load during online problem solving, Br. J. Educ. Technol. (2020). doi: 10.1111/bjet.12958.

[18] I. Arroyo, B. P. Woolf, W. Burelson, K. Muldner, D. Rai, M. Tai, A multimedia adaptive tutoring system for mathematics that addresses cognition, metacognition and affect, Int. J. Artif. Intell. Educ. 24 (2014) 387–426. doi: 10.1007/s40593- 014-0023-y.

[19] M. Dindar, J. Malmberg, S. Järvelä, E. Haataja, P. A. Kirschner, Matching self-reports with electrodermal activity data: Investigating temporal changes in self- regulated learning, Educ. Inf. Technol. 25 (2020) 1785–1802. doi: 10.1007/s10639-019-10059-5.

[20] H. J. Pijeira-Díaz, H. Drachsler, P. A. Kirschner, S. Järvelä, Profiling sympathetic arousal in a physics course: How active are students?, Journal of Computer Assisted Learning 34 (2018) 397–408. doi: 10.1111/jcal.12271.

[21] B. Kurdi, S. Lozano, M. R. Banaji, Introducing the Open Affective Standardized Image Set (OASIS), Behav. Res. Methods 49 (2017) 457–470. doi: 10.3758/s13428-016-0715-3.

[22] D.C. Menezes, 2019. Play Mode Blocks Engine. URL: https://assetstore.unity.com/packages/te mplates/systems/play-mode-blocks-engine-158224.

[23] Read JC, MacFarlane SJ, Casey C, Endurability, engagement and expectations: measuring children's fun, in : Proceedings of the International Workshop Interaction Design and Children, Shaker Publishing, Eindhoven, 2002.

[24] T. Magyaródi, H. Nagy, P. Soltész, T. Mózes, A. Oláh, Psychometric properties of a newly established flow state questionnaire, 2013.

[25] Benedek, M., & Kaernbach, C., Decomposition of skin conductance data by means of nonnegative deconvolution. *Psychophysiology 47* (2010) 647 – 658. doi: 10.1111/j.1469-8986.2009.00972.x.

[26] V. Jha, N. Prakash, S. Sagar, Wearable anger-monitoring system, ICT Express 4 (2018) 194–198. doi: 10.1016/J.ICTE.2017.07.002.

[27] G. Stemmler, Physiological processes during emotion, in: P. Philippot, R. S. Feldman (Eds.), The regulation of

emotion, 1st ed., Lawrence Erlbaum Associates Publishers, 2004, pp. 33–70. doi: 10.4324/9781410610898

[28] J. A. Russell, A. Weiss, G. A. Mendelsohn, Affect Grid: A single-item scale of pleasure and arousal., J. Pers. Soc. Psychol. 57 (1989) 493–502. doi: 10.1037/0022-3514.57.3.493.

[29] M. M. Bradley, P. J. Lang, Measuring emotion: The self-assessment manikin and the semantic differential, J. Behav. Ther. Exp. Psychiatry 25 (1994) 49–59. doi: 10.1016/0005-7916(94)90063-9.

Examining the impact of data augmentation for psychomotor skills training in human-robot interaction

Daniel Majonica[a,b], Deniz Iren[b] and Roland Klemke[a,b]

[a] Cologne Game Lab, TH Köln, Cologne, Germany
[b] Open Universiteit, Heerlen, The Netherlands

Abstract

Training psychomotor skills for human-robot interaction is generally done with a human trainer educating the human on how to handle the robot effectively and interact with it safely and efficiently. The dynamic interaction between a robot and a human requires complex machine learning algorithms to be modeled, and these algorithms rely on a large amount of data to be trained. Such data are collected by sensors when a human interacts with a robot. Consequently, the data must be annotated by an expert. Finally, with the annotated data, a psychomotor skills training model can be created to assist the training process. This is a time intensive and costly process. To ease the costs and cut down collection time, we propose the use of data augmentation.

Keywords 1

Human-robot interaction, data augmentation, machine learning

1. Introduction

Psychomotor skills constitute an essential element of human-robot interaction. The development of psychomotor skills requires hands-on practice. In most cases, the practiced skills need to be executed repetitively by the learner in order to, for example, build muscle memory and support further skill development. Moreover, structured instructions and feedback facilitate the learning process and allow safe performance of the practiced skills. Thus, an educational model for psychomotor skill training needs to support the timely communication of the instructions and feedback and must define how these instructions and feedback are presented to the learner. The educational model also supports the evaluation of the learning outcome. Currently, doing this in a remote manner makes the learning process ineffective and inefficient, usually hindering the beginner's learning progress. The project MILKI-PSY aims at improving the remote learning process of psychomotor skills. In this study, the data will be collected using the multimodal pipeline framework [1] which is used to handle multimodal data specifically.

Human-robot interaction describes the process of a human interacting with a robot in a shared physical environment. In certain cases, the human and the robot operate in a cooperative manner. To ensure a safe, efficient, and effective interaction requires training of both the robot and the human counterpart. Training humans in the handling of industrial robots is usually done by a human trainer. To assist the training of psychomotor skills, we propose a pedagogical approach. The goal of our pedagogical model is to facilitate a safe, effective, and efficient learning environment

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: dm@colognegamelab.de (A. 1); deniz.iren@ou.nl (A. 2); rk@colognegamelab.com (A. 3)
ORCID: 0000-0003-4792-0472 (A. 1); 0000-0002-0727-3445 (A. 2); 0000-0002-9268-3229 (A. 3)

CEUR Workshop Proceedings (CEUR-WS.org)

for the learner. Particularly, in this study, we focus on a collaborative assembly task between a human operator and an industrial robot in which they cooperate as depicted later in figure 2.

In this paper, we first go over the related work in the field of human-robot interaction. Then, we present three research questions that we aim to address in this Ph.D. research. Next, we will discuss how we are going to achieve this in the methodology part. Finally, we conclude with the expected impact and a discussion at the end of this paper.

2. Related work

Human-robot interaction is a field dedicated to understanding, designing, and evaluating robotic systems that interact with humans. Interaction, by definition, requires communication between the interacting parties, i.e., robots and humans. The communication between robots and humans may take completely different forms depending on the distance between them. Goodrich and Schultz [2] categorizes human-robot communication into two; proximate communication in which the communicating parties share the same space (physical or virtual) and remote communication where those parties are apart. In this study, we focus on an assembly task where the human operator shares the physical space with the robot. In our remote learning scenarios, we rely on immersive technologies where there is no physical robot but the operator and the virtual robot still shares the same virtual environment. Thus, the method of communication between the parties is proximate.

Training in human-robot interaction gradually becomes more important for the next generation of robot systems. Particularly, in cases of remote training or additional training outside of the conventional teaching methods, a user-friendly interface should be used [3] to improve the learning process. This user interface should be designed differently depending on the communication category.

Immersive user interfaces such as AR and VR model the behavior of the human and robot agents. The development of such behavioral models heavily uses machine learning techniques that rely on a large amount of data. Such data can be collected via environmental sensors and cameras that capture the activities of human and the robot while they interact. When expensive machines like industrial robots are used, data collection becomes costly and effort-intensive. In such environments the number of robots available for data collection purposes is also a limitation. Having a limit of one or two robots is not uncommon in data collection. On the other side, for most data collection, the limiting factor might be a machine-operating human which naturally is limited in the amount of data they can collect in a full day. To address the issue of data collection we propose data augmentation which is a family of techniques that allows us to synthesize realistic data.

Formally, data augmentation can be defined as techniques aiming at the creation of synthetic data [4] for the expansion of the size and/or the diversity of the dataset [5]. A sub-field of data augmentation is domain randomization [6]. Domain randomization can expose the machine learning model to many different variants of the same problem [7][8] and therefore, train the model more robustly. Another sub-field of data augmentation is domain adaptation, which aims to mitigate the covariate shift problem given that training and evaluation sets derive from the same distribution. Studies exist in the literature that indicate using domain adaptation can positively impact the performance of the machine learning model, especially in the domain of human pose detection for activities [5].

Using machine learning to categorize complex psychomotor activity data for educational purposes has been done before. For example, Spikol et al. [9] used multimodal learning analytics to collect and provide different data about the interaction between the learner and the system. In cases where the number of potential activity categories is significantly limited, such as the CPR tutor from Di Mitri et al. [10] and the table tennis tutor by Mat Sanusi et al. [11], using data augmentation might only marginally increase the results and therefore might not be feasible due to the initial workload that those algorithms take. On the other hand, human-robot interaction is a complex task and therefore might greatly benefit from data augmentation.

3. Research questions

The following research questions are the focus of this Ph.D. research. First of all, it is important to know what the current status in teaching human-robot interaction is and how humans are trained to handle industrial robots. This requires an extensive review of the literature that focuses on teaching humans how to use and operate robots.

1. What are the common practices and mistakes in human-robot interaction when handling industrial robots?

In order to allocate common practices in teaching human-robot interaction, it is crucial to know *what kind of instructions are given by the trainer* and *what kind of feedback is received by the trainee*. Moreover, we also aim to *examine the effect of various training approaches (i.e., static, variable, and dynamic) on the trainees learning progress*. Secondly, this study addresses current technologies that can support the training of psychomotor skills and facilitate the teaching of human-robot interaction.

2. What technological support is achievable in educational human-robot interaction?

When looking at technologies, the focus of this research relies on *what existing technologies cover both robots and humans* and also *what kind of machine learning technologies are available*. In this study, we will utilize immersive technologies that vary in terms of level of intrusion. For example, the use of a head-mounted display to provide feedback to the learner in an augmented reality setting has a lower level of intrusion than a completely simulated learning environment. Thirdly, it is important for this research to focus on the identification and classification of common mistakes made during psychomotor skills training with robots.

3. How can data augmentation assist the successful replication of common mistakes and how can we measure this impact?

To address this research question, we will consult experts in training humans on how to interact with industrial robots and classify the common mistakes that can take place. Then we will explore *how we can augment data in a meaningful manner to replicate common mistakes*.

4. Methodology

In this study, first we conduct a systematic literature review in the following fields of research: which are used in the domain of educational technologies.

1 Educational human-robot interaction
2 Technologies in human-robot interaction
3 Semi-supervised learning models
4 Data augmentation – Domain randomization

The first research field is educational human-robot interaction and it refers to the education of humans in handling industrial robots. This includes the common training practices as well as common mistakes the trainee makes during the interaction. In this study, we will use an industrial robot to assemble a box in cooperation with a human as seen in figure 2. First, the human learner will be trained on how to interact with the robot appropriately. Then, the learner will be instructed on the specifics of the assembly steps.

The second research field is the technologies used in human-robot interaction. This addresses data augmentation and domain randomization which are both active fields of development, and research papers about these topics in the domains of 3D pose detection [5] and object detection [4] are released frequently in recent years.

After the systematic literature review, the next step will be to design a theoretical framework. This framework includes the design for an immersive training environment specifically for psychomotor skills training. We will use the four-component instruction design (4C/ID) [12] method to create our framework. In 4C/ID, the design is split up into four different components. The first component is the learning tasks which aim at integrating skills and show a high variability of practice. The second component is the supportive

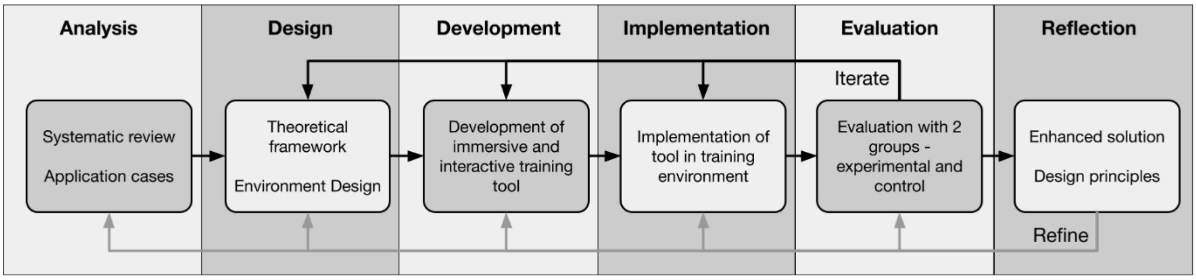

Figure 1: Design-based research (DBR) synthesis combined by DBR-models from Amiel & Reeves [15] and De Villiers & Harpur [14]. Showing the iterative research process in the domain of educational technologies

information which focuses on the performance of non-routine aspects of learning tasks. It is specified per task class and always available throughout the whole learning process. The third component is the part-task practice. This aims to provide additional practice for individual routines selected by either the trainer or trainee. The last component is procedural information. Procedural information specifies how to perform routine aspects of a task, for example by giving step-by-step instructions. This procedural information is presented just in time during training and is gradually less present with the increasing expertise of the trainee. In the case of designing a system for human-robot interaction, we will use 4C/ID to teach the human learner different aspects of handling industrial robots. 4C/ID provides a framework to handle non-repetitive tasks which include task non-specific repetitive elements. The psychomotor skills training in human-robot interaction has similar non-repetitive tasks which we are focusing on in this research.

The overall process of this research methodology is design-based research as illustrated in figure 1. The steps of design-based research include analysis, design, development, implementation, evaluation, and reflection. In contrast to predictive research, design-based research uses an iterative process. This means after evaluating the results, the entire process can be iterated based on the ADDIE (i.e., analysis, design, development, implementation, evaluation) model [13]. While a generic ADDIE model jumps from the evaluation step directly to the solution of the problem [14], this approach includes a reflective phase whereby all previous steps are examined and refined for the next iteration. This reflection and refinement of problems, solutions, methods, and design principles systemically tries to accommodate for innovative solutions for real-life problems [15].

In this study, we use machine learning to extrapolate from collected data and model the dynamic human-robot interaction environment. The process of data collection can take many forms. Using the physical environment for data collection has positive and negative aspects. On the positive side, collected data naturally captures and expresses the task that the robot has to perform. On the negative side, the data collection task has certain limitations such as, the availability and the speed of the robot and human, the limited amount of human-robot data collection stations (in most cases one or two robots), and the expected tiredness of the human. In order to counter these problems of data collection, we will be exploring data augmentation.

We are planning to develop multiple prototypes over the course of this research. The first prototype will be designed specifically for the human-robot interaction where both sides have to cooperate in order to assemble a box together. This prototype will use a virtual robot. In the prototype, the human learner can interact with the virtual robot which is a simulated 3D model visible through a camera or head-mounted display.

5. Expected Impact

By using data augmentation and generating synthetic data for modeling human-robot interaction, we expect the machine learning model to perform equally or better than a machine learning model trained on physical data alone. We also expect the data collection process to be faster and reusable in future applications. Examining the impact of data augmentation for psychomotor skills training in human-robot interaction, we hope to find a reliable and safe approach for training humans how to handle industrial robots.

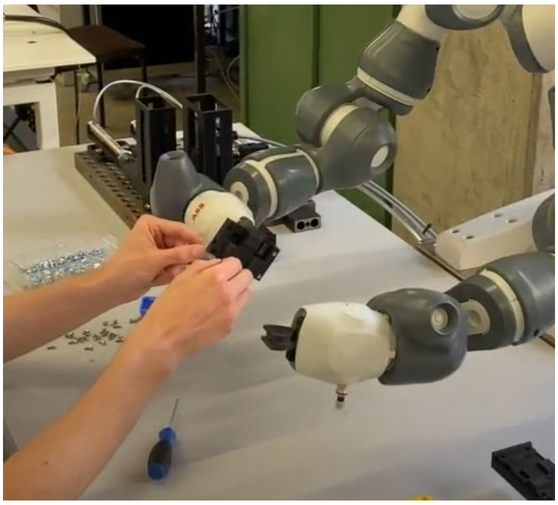

Figure 2: Recent human-robot interaction example with the industrial robot YuMi interacting with a human operator to assemble a box.

6. Conclusion

The training of psychomotor skills is imperative for an effective, efficient, and safe human-robot interaction. In this paper, we propose an educational approach towards the psychomotor skills training of humans in handling industrial robots. Our educational approach includes timely instructions and feedback as well as supporting immersive technologies. The development of such technologies requires machine learning techniques that rely on a large amount of data. However, it is costly and effort intensive to collect data in such settings where the availability of the robots is limited. To address this challenge, we propose the use of data augmentation.

We are going to investigate the impact of data augmentation on the performance of the machine learning models that represent the interaction between the human and the robot in a physical environment. In this study, we are going to conduct an extensive literature review in the domains of education for human-robot interaction, technologies used in human-robot interaction, and data augmentation. Then, a theoretical framework will be designed and an immersive training prototype will be developed. This prototype will be implemented and evaluated in the training environment.

7. Acknowledgements

This project was funded by the BMBF, the German Federal Ministry of Education and Research, under the MILKI-PSY (ger. abb. for Multimodal immersive learning with artificial intelligence for psychomotor training; https://www.milki-psy.de) Name and the grant code: 16DHB4013.

8. References

[1] D. Di Mitri, J. Schneider, M. Specht, H. Drachsler, Multimodal pipeline: A generic approach for handling multimodal data for supporting learning, 2019.

[2] M. A. Goodrich, A. C. Schultz, Human-robot interaction: a survey, Now Publishers Inc, 2008.

[3] M. Ishii, A robot teaching method using hyper card system, in: [1992] Proceedings IEEE International Workshop on Robot and Human Communication, 1992, pp. 410–412.

[4] S. Borkman, A. Crespi, S. Dhakad, S. Ganguly, J. Hogins, Y.-C. Jhang, M. Kamalzadeh, B. Li, S. Leal, P. Parisi, C. Romero, W. Smith, A. Thaman, S. Warren, N. Yadav, Unity perception: Generate synthetic data for computer vision, 2021.

[5] E. Spyrou, E. Mathe, G. Pikramenos, K. Kechagias,
P. Mylonas, Data augmentation vs. Domain adaptation—a case study in human activity recognition, Technologies 8 (2020).

[6] L. Weng, Domain randomization for sim2real transfer, lilianweng.github.io/lil-log (2019). URL: http://lilianweng.github.io/lil-log/2019/05/04/domain-randomization.html.

[7] J. Tobin, R. Fong, A. Ray, J. Schneider, W. Zaremba, P. Abbeel, Domain randomization for transferring deep neural networks from simulation to the real world, 2017.

[8] OpenAI, I. Akkaya, M. Andrychowicz, M. Chociej, M. Litwin, B. McGrew, A.

Petron, A. Paino, M. Plappert, G. Powell, R. Ribas, J. Schneider, N. Tezak, J. Tworek, P. Welinder, L. Weng, Q. Yuan, W. Zaremba, L. Zhang, Solving rubik's cube with a robot hand, 2019.
[9] D. Spikol, E. Ruffaldi, G. Dabisias, M. Cukurova, Supervised machine learning in multimodal learning analytics for estimating success in project-based learning, Journal of Computer Assisted Learning 34 (2018) 366–377.
[10] D. Di Mitri, J. Schneider, K. Trebing, S. Sopka, M. Specht, H. Drachsler, Real-time multimodal feedback with the cpr tutor, in: I. I. Bittencourt, M. Cukurova, K. Muldner, R. Luckin, E. Millán (Eds.), Artificial Intelligence in Education, Springer International Publishing, Cham, 2020, pp. 141–152.
[11] K. A. Mat Sanusi, D. D. Mitri, B. Limbu, R. Klemke, Table tennis tutor: Forehand strokes classification based on multimodal data and neural networks, Sensors 21 (2021) 3121.
[12] J. van Merriënboer, The four-component instructional design model: An overview of its main design principles. 4cid. org, 2019.
[13] M. Molenda, In search of the elusive addie model, Performance improvement 42 (2003) 34–37.
[14] M. De Villiers, P. Harpur, Design-based research-the educational technology variant of design research: illustrated by the design of an m-learning environment, in: proceedings of the South African institute for computer scientists and information technologists conference, 2013, pp. 252–261.
[15] T. Amiel, T. C. Reeves, Design-based research and educational technology: Rethinking technology and the research agenda, Journal of educational technology & society 11 (2008) 29–40.

Conceptualising immersive multimodal environments for psychomotor skills training.

Khaleel Asyraaf Mat Sanusi[a], Deniz Iren[b] and Roland Klemke[a,b]

[a] *Cologne Game Lab, TH Köln, Cologne, Germany*
[b] *Open Universiteit, Heerlen, The Netherlands*

Abstract

The coordination of psychomotor skills requires deliberate practice and techniques, all of which are typically taught in a physical setting, where instructions and timely feedback are given by the teachers. However, doing so remotely is commonly inefficient and ineffective, therefore, hindering the learner's progress. Sensors and immersive technologies enable the collection of multimodal data and the creation of immersion, respectively. These technologies have been widely used to further improve the learning outcome, especially in the psychomotor domain. In this paper, we present our research on designing an immersive training environment for remote psychomotor skill training and investigating how such an environment can be used for training skills in different psychomotor domains.

Keywords 1

Immersive technologies, Sensors, Multimodal, Psychomotor skills

1. Introduction

The global pandemic event of Covid-19 has affected various learning and teaching activities acutely. This necessitates the notion of online learning or e-learning in which web conferencing tools (e.g., Zoom, Teams) are widely utilised by teachers and students for classroom activities. However, this is rarely the case for psychomotor skills development as they require hands-on practice. Psychomotor skills need to be physically executed, in most cases, repetitively to the extent that the muscle memory is trained, which will automate the muscle movements [1]. Furthermore, the presence of teachers is needed in order to explain, demonstrate, and assess certain procedures. To achieve this, the human learning model has to be in a structured form where instructions are well-defined, and feedback can be given to ensure that the tasks are performed in a correct manner, which include safety and effectiveness. Timely and consistent feedback from the teacher is essential for the learner to avoid developing improper techniques during training, thus ensuring the desired goal can be achieved in a shorter time [2]. However, doing so in a remote manner makes the learning process ineffective and inefficient due to the lack of modalities such as haptic feedback or 3D full-body perception, hence impeding the learner’s progress. Due to this, psychomotor skill learners and teachers have been substantially affected.

Nowadays, educational technology and artificial intelligence (AI) researchers are progressively embedding sensor technologies for the collection of multimodal data, and machine learning approaches for tracking learners' behaviour and progress in authentic learning contexts. The combination of these technologies introduces new technological

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: ks@colognegamelab.de (A. 1); deniz.iren@ou.nl (A. 2); rk@colognegamelab.com (A. 3)
ORCID: 0000-0001-6766-4416 (A. 1); 0000-0002-0727-3445 (A. 2); 0000-0002-9268-3229 (A. 3)

affordances that can be leveraged in the psychomotor education, especially in a remote manner, to further improve the learning outcome.

Multimodality is a theoretical assumption that can be applied to provide more structure in sensors for exploring learning. The general idea of multimodality in learning comes from the theory of embodied communication. Based on this theory, humans use their whole bodies to communicate with each other, applying various channels to exchange messages such as gestures, facial expressions, prosody, etc. [3]. Subsequently, the trend of multimodality has been employed in human-computer interaction. Sensor-based multimodal interfaces allow the monitoring of different modalities and have been applied in various domains to improve learning [[4], [5], [6]].

While the multimodal approach helps to improve the psychomotor learning outcome, designing virtual training environments adds immersion to the learning activity. As such, immersive learning technologies such as virtual reality (VR), augmented reality (AR) and game elements enable the creation of virtual training environments or simulations that typically consist of nearly, if not entirely, realistic physical similarity to an actual learning context. Herrington et al. [7] stress that the learning environment and designated tasks create the conditions for the “True” immersion. Hence, it can be argued that the instructions and feedback provided by the learning environment should be pragmatic for the learners to learn to perform the tasks in a correct manner; for example, personalised feedback (human-teacher-like) to create immersive learning experiences. Intrinsically, virtual training environments allow the learner to actively interact with the in-game objects which may create more engagement and increase motivation for the learner when performing tasks.

In this research, we aim to design and implement an immersive training environment for psychomotor skills using immersive technologies which will be integrated with sensor technologies and AI, in order to deliver instructions and feedback to learners in a meaningful manner. Furthermore, we intend to investigate the effectiveness of the system and whether it can be applied to train skills in different psychomotor domains. The development of this system provides an early and significant step towards combining immersive technologies and sensor technologies in a multi-sensor setup for collecting multimodal data and giving immediate feedback in an immersive training environment in which learners can use to improve their psychomotor skills independently.

The paper is structured as follows. In Section 2, we present related studies that utilise sensors for the collection of multimodal data and immersive training environments for immersion, and to what extent they are used in the psychomotor domain. Next, we explain our research questions in Section 3. Subsequently, in Section 4, we visualise and describe the research model and methods of this study. Finally, in Section 5 we discuss the expected outcomes of our study in theoretical and practical implications, followed by the conclusion.

2. Related work

2.1. Sensors in psychomotor learning

Sensor technologies are increasingly becoming more portable and increasingly used in psychomotor training, enabling efficient methods for the acquisition of performance data, which allows effective monitoring and intervention. That being said, such devices have been explored to provide support in the learning domain. For example, Schneider et al. [8] analysed 82 prototypes found in literature studies based on Bloom’s taxonomy of learning domains (psychomotor, cognitive, and affective). Their research suggests researchers and educators to consider utilising sensor-based platforms as reliable learning tools for reducing the workload of teachers and, therefore, contribute to the solution of many current educational challenges.

Motion sensors such as accelerometers and gyroscopes are predominantly used to acquire motion data to recognize human activities, especially in the psychomotor domain. These sensors are commonly combined and used in a synchronized manner to achieve a higher accuracy of detecting not only simple but complex activities as well [9]. This enables the collection of multimodal data and provides a more accurate representation of the learning process [10]. Furthermore, multimodal data can be collected using various sensors such as wearable sensors, depth camera sensors, Internet of Things devices, etc.

For instance, Schneider et al. [4] designed a system to support the development of public speaking skills using the Kinect v2 depth camera sensor to track the skeletal joints of the learner's body and the HoloLens headset to provide feedback in real-time when mistakes are detected while presenting. Limbu et al. [11] developed a system to teach basic calligraphy skills, which uses the pen sensor in Microsoft Surface tablet and EMG sensors in a Myo armband to provide feedback to learners during practice. It also allows the calligraphy teacher to create an expert model, which the learners can later use to practice and receive guidance and feedback based on the expert model.

To better understand learners' performance, educational researchers are progressively using machine learning approaches to classify activities based on the multimodal data collected. For instance, in the medical domain, Di Mitri et al. [5] investigated how multimodal data and Neural Networks can be used for learning Cardiopulmonary Resuscitation skills by utilising a multi-sensor system comprising of a Kinect v2 and a Myo armband. In the sports domain, Mat Sanusi et al. [6] applied the same framework as the previous author by using built-in accelerometer and gyroscope sensors in a smartphone and also a Kinect v2 to detect forehand table tennis strokes during training. Both study results show a high classification rate of the activities when combining the sensors, emphasising the importance of a multimodal approach in classifying complex activities.

In this research, we aim to use a multi-sensory system (e.g., wearable technologies, depth cameras) with the help of machine learning to help learners improve their psychomotor skills. We intend to have a theoretical framework that can be used for training skills in one psychomotor domain and subsequently applied in multiple domains.

2.2. Immersive training environments

Immersive learning technologies such as VR and AR are progressively becoming a significant medium for psychomotor training. Due to the substantial improvement and development in recent years, such technologies are being used in various psychomotor domains, including sports, physical training, rehabilitation therapy, and much more. These technologies transport individuals into an interactive training or learning environment, either virtually or physically, to replicate the authentic learning context of a specific skill.

For example, Song et al. [12] designed and implemented an immersive VR environment for teaching tennis using high-definition stereoscopic display, robust and accurate hybrid sensor tracking, shader-based skin deformation, intelligent animation control, and haptic feedback mechanism. The authors reported that, through these technologies, a real-time immersive tennis playing experience is achieved. Potentially, the system can be scaled to adapt various application cases such as other sports game simulations and even military training simulations.

Ali et al. [13] experimented with multiple VR fitness applications (e.g., VR Fitness, VirZOOM, BOXVR) for physical training such as walking, running, and jogging. In addition, they implemented a mobile application that uses built-in sensors such as an accelerometer and gyroscope for motion detection. As a result, they achieved up to 82.46% of accuracy and thus, described the effectiveness of VR technology in physical training, which is helpful for the development of psychomotor skills.

In our research, we aim to incorporate immersive technologies into the mix for the creation of immersive training environments to enhance the immersive experience of the learner in the learning setting. Our grand vision is to have a theoretical framework with a structured human learning model (feedback and instructions) within these immersive training environments that can be applied to not only one but also multiple psychomotor domains.

3. Research questions

Based on the problem identified and the related work analysed, we aim to investigate the following research questions (RQs):

1. What level of technological support (technology) is available in the literature and appropriate for delivering effective instructions and feedback

(pedagogy) to the learners in psychomotor training?

Fundamentally, it is crucial to identify *the most promising pedagogical approaches in psychomotor skills learning* that can be applied in multiple psychomotor domains. Furthermore, with technologies that have been widely used to improve the learning outcome in recent years, we survey *the state-of-the-art of technology that may potentially be helpful* for our research. Therefore, a systematic review will be carried out for these two processes and thus, answer our RQ1. The outcome of answering this question would be the theoretical framework of the system.

2. How can we create an immersive and information-rich (remote/self-learning) training environment for psychomotor skills that deliver effective instructions and meaningful feedback to the learner?

Subsequently, we design and implement a virtual training environment based on the theoretical framework retrieved from RQ1. The instruction and feedback systems should be given in a realistic manner to create immersive learning experiences. Therefore, it is vital to research *how can we maximise the system's effectiveness in providing feedback and instructions.* This includes the framing of interaction and the appropriate modalities for instructions and feedback. Consequently, we can investigate the effectiveness of the system: *can the system help learners improve their skills during training?*

3. To what extent can we generalise our training framework to multiple psychomotor domains?

Finally, we explore if the system can, both theoretically and practically, be adapted and applicable in multiple psychomotor domains. More exercise routines and common mistakes of the selected applications cases will be identified to suit the system's needs. Hence, it is crucial to know *what are other possible application cases that the new system can be used to train related psychomotor tasks* and *can the system effectively help learners learn different psychomotor skills?*

4. Methodology

4.1. Research methods

It is essential for this research to follow a methodological approach for designing, developing, testing, and evaluating such a system. Hence, we conduct our research based on the Design-based Research (DBR) approach, a common iterative methodological approach for prototypical solutions. In the context of our research, we combined two DBR models from Amiel & Reeves [14], and De Vielliers & Harpur [15], which are used in the domain of educational technologies.

Figure 1 shows the phases of the DBR approach for this research, and the following subsections explain each of the phases.

1. *Problem analysis:* In the first phase, a systematic literature will be reviewed to determine the importance of the problem and identify the current theory on the immersive multimodal environments in the psychomotor domain. Furthermore, the selection of application cases will be made in this phase. With these approaches, we are analysing the problem and defining research goals. The outcome of this step is a detailed research proposal containing goals and evaluation criteria.

2. *Design solution*: A theoretical framework is proposed based on the results from the systematic review, identifying the most promising pedagogical model in psychomotor training and the technologies that can be contributed to such a model. Our conceptual model (see Figure 2) states how we transfer the theoretical framework into our system design, suggesting to address the problem from phase 1.

3. *Develop solution*: The next phase is the implementation of the immersive training environment that serves the research purpose. The development of the system is based on the theoretical framework proposed in phase 2. The outcome is an innovative and functional immersive training environment system with the integration of immersive technologies, sensor technologies, and AI that aims to address the challenges of remote psychomotor training and help us achieve our research goals.

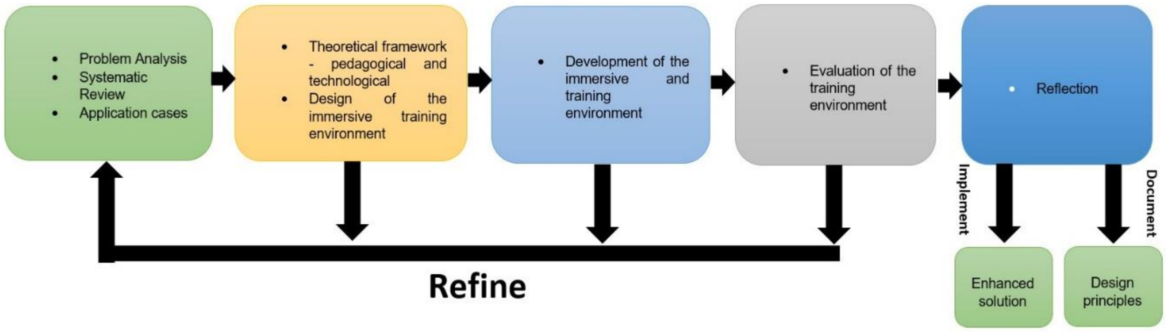

Figure 1: The synthesised model for DBR in the context of this research [[14], [15]].

4. *Evaluate in practice*: Subsequently, in the next phase, focus group experiments involving the teachers/experts will be carried out for

qualitative analysis to gather important details that can be added to the system. Further, a user test will be conducted to reveal essential aspects of how the system can be improved. Additionally, questionnaires and surveys for the quantitative analysis are helpful to provide a general idea of how users perceive the interaction between the system. The refinement of the system should then be followed involving the teachers/experts to ensure that the system is ready to be tested with the learners in the real-world setting. Then, the data is collected and analysed to answer the research questions and to construct design principles.

5. *Reflection, dual outcomes*:

Practical: This phase enhances the implementation of the solution. As reflection occurs, new designs can be further developed and implemented, which leads to an ongoing sub-cycle of the design-reflection process.

Theoretical: It is imperative to keep detailed records during the design research process concerning how the design outcomes (e.g., principles) have worked or have not worked, how the innovation has been improved, and what are changes have been made. Through this documentation, it can be helpful for other researchers and designers who are interested in those findings and examine them in relation to their context and needs.

4.2. Solution approach

In learning sciences, a conceptual model is commonly used to improve explanations and provide visual representations of abstracts [16]. Following this theory, we sketched a model for visualising the overall learning process using the immersive training environment from the human learner perspective (see Figure 2).

Based on the model, multimodal data will be collected by tracking the skeletal points and capturing the body motion of the human learner's body. Instructional tasks are ideally given before the learner performs the specific tasks. Feedback is typically given in real-time when mistakes are detected during training and as visual summative, after training. Instructions are also given during training to help learners progress to the next steps or even in the form of detailed feedback. These two aspects of the human learning model - instructions and feedback - can be given in multiple modalities. In the context of our research, the most common modalities that can be applied are visual, audio, and haptic. These modalities form various types of interaction that can be potentially used in the immersive training environment to give instructions and feedback such as virtual avatars, videos, etc. Finally, these aspects help validate the effectiveness of the immersive training environment.

Since the research is in an early phase, the conceptual model is still on the abstract level. However, this constitutes the groundwork of this research and will be extended into a bigger model with more aspects in the later phases.

5. Discussion and conclusion

The expected outcomes of this research are divided into two implications: theoretical and practical. From the theoretical perspective,

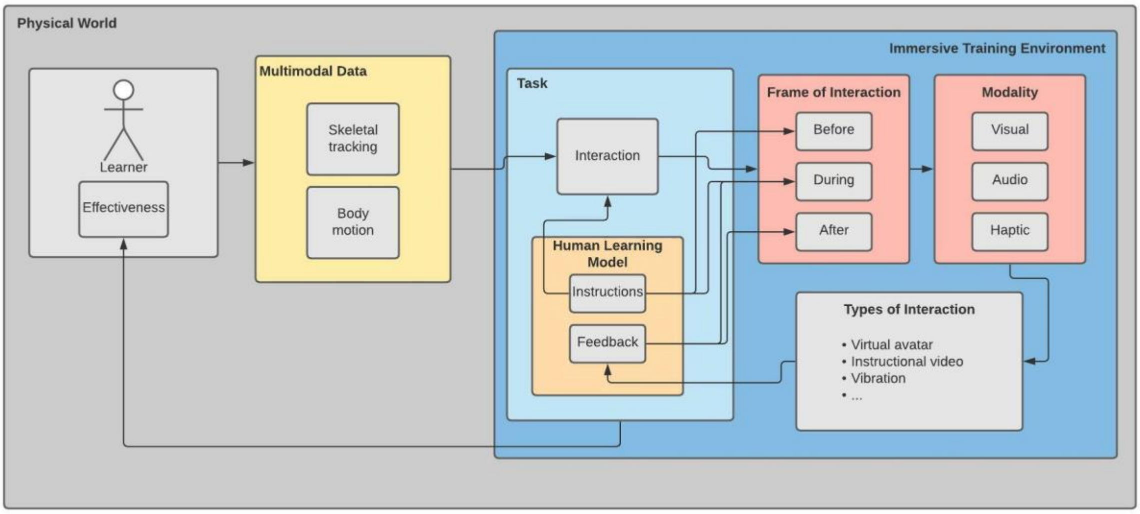

Figure 2: The conceptual model of this research.

systematic literature review findings on requirements to create immersive training environments for psychomotor skills will be delivered. Based on these findings, a conceptual framework of the immersive training environment consisting of guidelines and methodologies on delivering instructions, providing feedback, and tracking learner's performance will be constructed. We envision this framework to constitute the groundwork for the design. Moreover, it will extend immersive training environments for psychomotor skills training in multiple domains. This framework will potentially be useful for researchers as a basis for their theoretical and practical research.

From the practical perspective, a system for delivering effective instructions, providing meaningful feedback, and tracking learner's performance will be developed. Similarly, as the theoretical implication, such a system needs to be adapted in various psychomotor domains for different skills training. The empirical studies will be carried out with learners to measure the effectiveness of the system and the outcome should deliver promising results. Consequently, learners and teachers can benefit from the system to help them with the training.

This research investigates the effectiveness of an immersive training environment in the development of psychomotor skills training. The proposed theoretical framework integrates immersive technologies and sensor technologies for the immersion and multimodal data, respectively, providing a preliminary yet significant step towards combining such technologies in a multi-sensor setup to further improve the learning outcome in the psychomotor domain, especially in remote-learning scenarios.

6. Acknowledgements

This research is funded by the Federal Ministry of Education and Research (BMBF) in the program of Digital Higher Education for the project Multimodal Immersive Learning with Artificial Intelligence for Psychomotor Skills (MILKI-PSY) with the grant number: 16DHB4013.

7. References

[1] R. W. Barnes, Surgical handicraft: Teaching andlearning surgical skills, The American Journal ofSurgery 153 (1987) 422–427. Papers of the NorthPacific Surgical Association.

[2] A. Ericsson, M. Prietula, E. Cokely, The making of an expert harvard business review (july–august 2007), Expert Harvard Business Review,July–August (2007).

[3] I. Wachsmuth, M. Lenzen, G. Knoblich, Embodied communication in humans and machines, Oxford University Press, 2008.

[4] J. Schneider, D. Börner, P. van Rosmalen, M. Specht, Can you help me with my pitch? studying a tool for real-time automated feedback, IEEE Transactionson Learning Technologies 9 (2016) 318–327.

[5] D. Di Mitri, J. Schneider, K. Trebing, S. Sopka, M. Specht, H. Drachsler, Real-time multimodal feedback with the cpr tutor, in: I. I. Bittencourt, M. Cukurova, K. Muldner, R. Luckin, E. Millán (Eds.), Artificial Intelligence in Education, Springer International Publishing, Cham, 2020, pp. 141–152.

[6] K. A. Mat Sanusi, D. D. Mitri, B. Limbu, R. Klemke, Table tennis tutor: Forehand strokes classification based on multimodal data and neural networks, Sensors 21 (2021) 3121.

[7] J. Herrington, T. C. Reeves, R. Oliver, Immersive learning technologies: Realism and online authentic learning, Journal of computing in Higher Education 19 (2007) 80–99.

[8] J. Schneider, D. Börner, P. Van Rosmalen, M. Specht, Augmenting the senses: A review on sensor-based learning support, Sensors 15 (2015) 4097–4133.

[9] A. Dias Pereira dos Santos, K. Yacef, R. Martinez-Maldonado, Let's dance: How to build a user model for dance students using wearable technology, in: Proceedings of the 25th Conference on User Mod-eling, Adaptation and Personalization, UMAP '17,Association for Computing Machinery, New York, NY, USA, 2017, p. 183–191.

[10] P. Blikstein, M. Worsley, Multimodal learning analytics and education data mining: using computational technologies to measure complex learning tasks, Journal of Learning Analytics 3 (2016) 220–238.

[11] B. H. Limbu, H. Jarodzka, R. Klemke, M. Specht, Can you ink while you blink? assessing mental effort in a sensor-based calligraphy trainer, Sensors19 (2019).

[12] P. Song, S. Xu, W. T. Fong, C. L. Chin, G. G. Chua, Z. Huang, An immersive vr system for sports education, IEICE TRANSACTIONS on Information and Systems 95 (2012) 1324–1331.

[13] S. F. Ali, S. Noor, S. A. Azmat, A. U. Noor, H. Siddiqui, Virtual reality as a physical training assistant, in: 2017 International Conference on Information and Communication Technologies (ICICT), IEEE, 2017,pp. 191–196.

[14] T. Amiel, T. C. Reeves, Design-based research and educational technology: Rethinking technology and the research agenda, Journal of educational technology & society 11 (2008) 29–40.

[15] M. De Villiers, P. Harpur, Design-based research the educational technology variant of design research: illustrated by the design of an m-learning environment, in: proceedings of the South African institute for computer scientists and information technologists conference, 2013, pp. 252–261.

[16] G. D. Chittleborough, D. F. Treagust, Why models are advantageous to learning science, Educación química 20 (2009) 12–17.

Towards using pedagogical agents to orchestrate collaborative learning activities combining music and mathematics in K-12

Eric Roldán Roa[a], Irene-Angelica Chounta[b], and Margus Pedaste[a]

[a] *University of Tartu, Ülikooli 18, Tartu, 51005, Estonia*
[b] *University of Duisburg-Essen, Forsthausweg 2, Duisburg, 47057, Germany*

Abstract

Research on pedagogical agents (PAs) focuses on personalizing and adapting content and instruction to students' diverse needs to support learning. Teachers can use this technology to support individual students' work. However, it is not clear what could be the impact of a PA that helps teachers to orchestrate collaborative learning activities on the classroom level. Our work explores two dimensions. Firstly, the effects of employing a PA in a technology-enhanced learning setting to promote students' motivation and learning outcomes. To that end, we will conduct a series of studies employing various methods and data (tests, questionnaires, observations, and students' performance data). Secondly, this work aims to develop a design framework based on teachers' expectations and needs when using a PA to orchestrate collaborative learning tasks. To build the PA design framework, we will conduct a study to categorize teachers' PA expectations and needs, accompanied with findings from the literature. Our hypothesis is that classrooms, where the PA is used to support teachers in the learning activity, will demonstrate high learning gains and students' perceived motivation.

Keywords

Pedagogical agent, collaboration, class orchestration, music and mathematics.

1. Introduction

1.1. Pedagogical agents

Pedagogical agents (PAs) are lifelike virtual characters playing an educational role, aiming to facilitate learning in digital learning environments (DLE) [1]. For instance, PAs facilitate learning by providing students with scaffolding [2] and guidance [3]. PAs can be combined with the support of various forms, such as text, voice, 2D or 3D character, and human-like appearance [4]. The roles PAs can play in the DLE, may include tutor [5], expert, mentor, motivator [6] student [7] Depending on the PA system, the behaviour of the agent can support cognitive, metacognitive [2] motivational, or social [8] aspects of learning.

Integrating PAs in learning digital systems goes in line with social learning theory [9]. The main premise of this theory is that learning is a social contextualized process, thus, in digital learning systems, PAs serve as a social entity that can simulate real-life interactions, such as role modelling. However, reviews discuss mixed evidence on the benefits PAs can have on learning [1, 10]. For instance, Schroeder et al. [10] meta-analysis reported a small but statistically significant ($g = .19$, $p < .001$) learning effect in favor for agent-based systems. They found this effect to be prominent in K-12 education and discussed that motivational benefits may be related to this

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: eric.roldan.roa@ut.ee (A. 1); irene-angelica.chounta@uni-due.de (A. 2); margus.pedaste@ut.ee (A. 3)
ORCID: 0000-0002-7519-4933 (A. 1); 0000-0001-9159-0664(A. 2); 0000-0002-5087-9637 (A. 3)

positive result. Kim & Baylor [6] suggests that a single agent design or behaviour can't fit all students' needs. Therefore, they stress the importance of designing the PA with the appropriate persona and media features to adequately support every student's learning process.

Literature shows that PAs can contribute to the motivation of students at an individual level [8]. Our research interest is whether a PA that targets the classroom as a whole, would have a similar impact on students' motivation, thus, better learning outcomes.

1.2. Collaboration and technology

Dillenbourg [11] defines collaborative learning as the situation in which two or more people learn or attempt to learn something together. The research field that explores how technology impacts and can promote collaboration is computer supported collaborative learning. Stahl et al. [12] have defined this as the field to study how learning can be scaffolding in computer-supported collaboration scenarios. We first need to contextualize the collaborative learning scenario to design appropriate scaffolding towards the reinforcement of domain knowledge acquisition and collaboration. To that end, we will build on a technology-enhanced method that combines music and mathematics in collaborative learning tasks [13]. In this case technology is used both on the individual and classroom level.

1.3. Music and mathematics

According to Tobias [14], teaching and learning experiences that are not based on a traditional mathematics curriculum can bridge the achievement gap and reduce mathematical anxiety. To that end, we argue that combining mathematics with music may potentially help to bridge the achievement gap and reduce anxiety. However, it is not evident what pedagogical strategies need to be considered to ensure this successful combination. For instance, Vaughn [15] found that there was a positive association between the voluntary study of music and mathematical achievement. It is important to note that in Vaughn's study, the academic and learning activities did not occur in the same learning space. Conversely, when arts are used as a vehicle for teaching mathematics in the same session instead of a different parallel activity, it contributes positively to learning outcomes as it helps to: (i) promote communication among students; (ii) transform learning environments; (iii) reach students that otherwise may not be reachable; (iv) offer new challenges to successful students; (v) decrease curricula fragmentation; (vi) connect in-school learning with real-world, among others [16] [17]. This was also confirmed by a study from An et al. [18] which demonstrated that integrated music and math lessons have a positive impact on multiple mathematical abilities.

1.4. Classroom orchestration and technology

PAs are typically used to support students on the individual level, while it is not clear how a PA can be used in the classroom as a teacher's support in classroom orchestration. Dillenbourg [19] defined classroom orchestration as a teacher's ability to manage, in real-time, the activities and contextual constraints inherent to the learning session. This managerial instance encompasses the nature of the activity (for example, individual, teamwork, class-wide), the pedagogical tools (such as simulations, wikis, quizzes), and the distribution channels (for example laptops, tablets, smartPhones). Conversely – and complementary – to instructional design and adaptive learning, classroom orchestration deals with extrinsic activities (moving chairs, collecting papers, checking on students' activity status, student log-in problems) and extrinsic constraints (discipline, limited lesson time, energy management, classroom physical space) [19]. Regarding the technological aspects, related work has explored teachers' needs for educational technologies. For example, Holstein et al. [20] showed that teachers expressed their wish to be able to see students thinking process and being able to adopt system-like features like monitoring all students at the same time. Furthermore, another case study by Chounta et al. [21] showed that teachers would like to receive support to be more efficient and effective in their practice. The authors convey the message that systems including artificial intelligent techniques, could

address such teachers' needs. Amarasinghe et al. [22], presented the notion of orchestration agents, which can help teachers by suggesting orchestration actions, thus offloading decision-making responsibilities whilst respecting their agency. They referred to the latter scenario as a hybrid human-machine approach. Our work expands on what teachers expect from a PA (in the form of a 2D character) helping them at a classroom level and exploring the impact of a hybrid system solution for K-12 education.
For our PA system, we envision the agent helping teachers with the activities as well as orchestration decisions. One example of an activity employed at a classroom level can be found in Chin et al. [23]. In this case, the feature allowed the teacher to show on a projected screen students' teachable agents with the aim to discuss on agents' different answers, hence, students understanding. Additionally, we are taking inspiration from existing PA systems targeting mathematics [2] [8]. However, our approach is different from the aforementioned studies in that the learning activities combine music and mathematics as means to motivate and support students' conceptual and procedural knowledge understanding.

1.5. Research questions

To understand how PA technology could support social dimensions on the classroom level rather than the individual level, we further investigate when and how a PA can help teachers in collaborative learning activity while motivating students to learn and be engaged in the task. To that end, the PA will be used in the classroom by integrating a virtual character to assist the teacher. We are interested to see whether employing a PA in the classroom makes a difference in terms of learning outcomes and contribute to students' motivation in the collaborative activity. In this study, we examine the following research questions (RQs):

[RQ1] Which kind of interventions and affordances do the current PA systems in K-12 education have for teachers at a classroom level?
[RQ2] What do teachers expect and need from a PA helping them to instruct and orchestrate collaborative learning activities?
[RQ3] What is the impact, in terms of learning gains and motivation, when employing a PA hybrid system at a classroom level?
[RQ4] What benefits, challenges, and constraints can be seen when employing a PA at a classroom level?

2. Methodology outline

In this study, we have selected a mixed-method approach. In terms of qualitative research, we will conduct a literature review and a case study to develop the design framework for our PA. In terms of quantitative research, we will conduct a series of studies to report on the learning outcomes and perceived students' motivation via tests and questionnaires. We elaborate more on the planned studies in the next sections.

2.1. Participants

For the case study, we plan to carry out focus groups with teachers (n = 5 to 7) to understand their expectations and needs when using a PA as orchestration support at a classroom level. The target population are mathematics teachers from primary education. For the pilot study, we will test the PA in one elementary classroom (n = 15-30 students). This will allow us to modify and adjust the PA system as well as our planned measuring instruments. Finally for the main study, we will employ the PA system in elementary classrooms (n = (4 to 8) including experimental and control groups) to evaluate the PA design framework based on teachers' insights, and to evaluate students' (100-200) learning gains and perceived motivation.

2.2. Materials

Pedagogical Agent and learning activities. For the PA system, we are using a face tracking solution, the agent can emulate gestures, eye blinking, lip-synching to a sound source, and head swing. Additionally, by key commands, the agent can walk, run, wave, point out, and trigger special moves (i.e., thinking pose, wearing glasses, eating a banana). On the other hand, for the learning activities, we want to build on prior research done with an educational game that combines music and mathematics in the format of a board game and a digital version. In the case of the board-game format, two elementary schools in Belgrade, Serbia, played the game for two sessions. Students were randomly assigned to play in small groups and to answer questionnaires targeting their learning experience. The results showed that the educational game supported their cognitive development while boosting their motivation and desire to have success on the learning tasks [24]. Building on the latter study, we used the digital version of the game and focused on group formation strategies and learning outcomes [13]. Using students' prior knowledge (as assessed by pre-knowledge tests), authors formed homogeneous (high or low performers only) and heterogeneous (high and low performers mixed together) groups and explored whether their game performance would be reflected on students' learning gains. Conversely to related research [25], the aforementioned study reported students belonging to heterogeneous condition to benefit less than homogeneous groups in terms of learning gains. However, this was not the case for the game score, where HE groups outperformed HO groups playing the game [13]. This article is particularly relevant because we are considering the authors' suggestions to better align the educational game with the learning goals and to enhance the collaboration activities.

Instruments. Furthermore, we will create an interview protocol and we will carry out teachers' focus groups. The aim is to develop a design framework based on their expectations and needs when collaborating and employing a pedagogical agent in the classroom. Regarding the students, they will be asked to answer a questionnaire (still to be defined) targeting motivation, from which we will analyze and report on PA effects and design challenges. Finally, we will use students' data to find a possible correlation between their perceived motivation and their learning outcomes (pre-post tests evaluation).

2.3. Study design and procedure

In the following figure (Figure 1) we present and describe the aim of the planned studies and timeline. We link each study to our research questions.

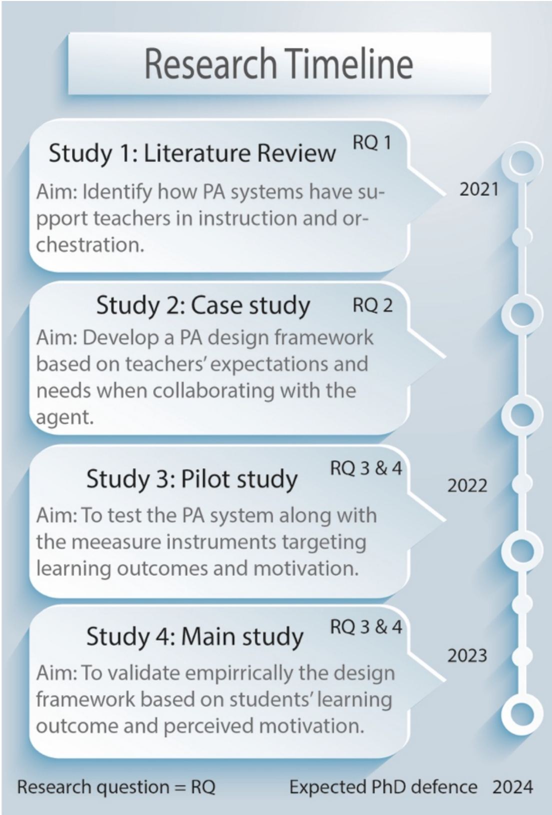

Figure 1: Research timeline and plan.

We will adapt collaborative learning activities with and without the PA (independent variable), as they will serve as the educational context of the experiments. We will divide half of the participating school groups of students into experimental condition (with PA) and control group (without PA). Our dependent variables are, on one hand, students' performance (as assessed by pre and post knowledge tests) along with their perceived motivation when working with or without the agent (questionnaires); and on the other hand, teachers' evaluation of the PA when facilitating the orchestration of the collaborative tasks.

We hypothesize that the experimental group will benefit more from having a PA helping the teacher to orchestrate the collaborative learning activity. The benefits will be reflected in terms of students' learning outcomes and motivation. On the other hand, we expect teachers to evaluate the PA system in the expected dimensions we will be able to find after concluding the case study with them.

3. Progress so far

We are currently in the process of conducting a systematic literature review (SLR) considering all types of PAs addressing mathematics education in K-12 education. The aim is to identify all pedagogical affordances these systems offer teachers when PAs are used on a classroom level. We envision the findings of the latter will support us in designing and proposing a theoretical framework for teachers' interventions in PA systems, and to classify PA systems affordances when using them on the classroom level for supporting instruction and orchestration activities. In parallel, we are in the process of conducting focus groups to understand teachers' expectations and needs when having a PA helping them to orchestrate collaborative activities in the classroom. From both, the SLR and the case study, we aim to have the pedagogical and orchestral design requirements to be met by the PA.

Technology wise, currently, we are performing tests with the PA system in real-time in remote teaching settings (video conferencing platforms) and classrooms settings by using projection. The aim is to test and adjust PA social cues, signals, reactions [26], and social fidelity contributors (i.e., personalization, slang, politeness, enthusiasm, interactivity) [27].

4. Theoretical and practical contributions

We envision that this research will contribute to the field of PA by bringing teachers' perspectives and needs when having the agent in a classroom collaborative setting. Moreover, by using PA systems technology at a classroom level, it could create a bond between the agent and student that could impact learning outcomes. Finally, this study will report on an innovative technology-enhanced learning scenario, and future research could potentially expand on the psychological, collaborative, and social effects this technology may bring for both teachers and students.

5. References

[1] N. L. Schroeder, C. M. Gotch. Persisting issues in pedagogical agent research, Journal of Educational Computing Research 53(2) (2015), 183–204. doi:10.1177/0735633115597625.A.

[2] N. Matsuda, W. Weng, N. Wall. The effect of metacognitive scaffolding for learning by teaching a teachable agent, Journal of Artificial Intelligence in Education 30(1) (2020) 1–37. doi:10.1007/s40593-019-00190-2.

[3] J. Kinnebrew, G. Biswas. Modeling and measuring self-regulated learning in teachable agent environments, Journal of e-Learning and Knowledge Society 7(2) (2011), 19–35. doi:10.20368/1971-8829/518.

[4] A. S. D. Martha, H. B. Santoso. The design and impact of the pedagogical agent: a systematic literature review, Journal of Educators Online 16(1) (2019) 1–15. doi:10.9743/jeo.2019.16.1.8.

[5] A. C. Graesser. Conversations with AutoTutor help students learn, International Journal of Artificial Intelligence in Education 26(1) (2016) 1–15. doi: 10.1007/s40593-015-0086-4.

[6] Y. Kim, A. L. Baylor. Research-based design of pedagogical agent roles: a review, progress, and recommendations, International Journal of Artificial Intelligence in Education 26(1) (2016) 160–169. doi:10.1007/s40593-015-0055-y.

[7] N. Matsuda, E. Yarzebinski, V. Keiser, R. Raizada, W. W. Cohen, G. J. Stylianides, K. R. Koedinger. Cognitive anatomy of tutor learning: lessons learned with SimStudent, Journal of Educational Psychology 105(4) (2013), 1152–1163. doi:10.1037/a0031955.

[8] B. Sjödén, A. Silvervarg, M. Haake, A. Gulz. Extending an educational math game with a pedagogical conversational agent: facing design challenges, Interdisciplinary Approaches to Adaptive Learning: A Look at the Neighbours, ITEC (2010), volume 126 of Communications in Computer and Information Science, Springer, Berlin, Heidelberg (2011). doi:10.1007/978-3-642-20074-8_10.

[9] A. Bandura. Human agency in social cognitive theory. American Psychologist 44(9) (1989), 1175–1184. doi:10.1037/0003-066X-44-9-1175.

[10] N. L. Schroeder, O. O. Adesope, R. B. Gilbert. How effective are pedagogical

agents for learning? A meta-analytic review, Journal of Educational Computing Research 49(1) (2013), 1–39. doi:10.2190/EC.49.1.a.

[11] P. Dillenbourg, What do you mean by collaborative learning?, in: P. Dillenbourg (Ed.), Collaborative-Learning: Cognitive and Computational Approaches, Elsevier, Oxford, 1999, pp. 1–19.

[12] G. Stahl, T. Koschmann, D. Suthers, Computer-supported collaborative learning: an historical perspective, in: R. K. Sawyer (Ed.), Cambridge Handbook of the Learning Sciences, Cambridge University Press, Cambridge, 2006, pp. 409–426.

[13] E. Roldán Roa, É. Roldán Roa, I.-A. Chounta, Learning music and math, together as one: towards a collaborative approach for practicing math skills with music, Volume 1232 of Collaboration Technologies and Social Computing, Springer International Publishing, 2020, pp. 143–156. doi:10.1007/978-3-030-58157-2-10.

[14] S. Tobias, C. Weissbrod, Anxiety and mathematics: an update, Harvard Education Review 50(1) (1980), 63–70. doi:10.17763/haer.50.1.xw483257j6035084.

[15] K. Vaughn, Music and mathematics: modest support for the off-claimed relationship, Journal of Aesthetic Education 34(3/4) (2000), 1175–1184.

[16] E. B. Fiske, Champions of Change: The Impact of the Arts on Learning, Arts Education Partnership and President's Committee on the Arts and Humanities, Washington, DC, 1999.

[17] H. L. Erickson, Concept-Based Curriculum and Instruction: Teaching Beyond the Facts, Corwin Press, Thousand Oaks, CA, 2002.

[18] S. An, M. M. Capraro, D. A. Tillman, Elementary teachers integrate music activities into regular mathematics lessons: effects on students' mathematical abilities, Journal for Learning through the Arts, 9(1) (2013). doi:10.21977/D99112867.

[19] Dillenbourg, P (2013). Design for classroom orchestration. Computers & Education, 69, 485-492. doi: 10.1016/j.compedu.2013.04.013

[20] K. Holstein, B. M. McLaren, V. Aleven. Intelligent tutors as teachers' aides: exploring teacher needs for real-time analytics in blended classrooms, Proceedings of the Seventh International Learning Analytics & Knowledge Conference (2017), 257–266. doi:10.1145/3027385.30.27451

[21] I.-A. Chounta, E. Bardone, A. Raudsep, M. Pedaste, Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education, International Journal of Artificial Intelligence in Education (2021). doi:10.1007/s40593-021-00243-5.

[22] I. Amarasinghe, D. Hernández-Leo, K. Manathunga, A. Jonson. Sustaining Continous Collaborative Leearning Flows in MOOCs: Orchestration Agent Approach. Journal of Universal Computer Science, vol. 24, no 8 (2018), 1034-1051.

[23] E. D. B. Chin, I. M. Dohmen, B. H. Cheng, M. A. Oppezzo, C. C. Chase, D. L. Schwartz. Preparing students for future learning with teachable agents, Education Tech Research Dev (2010). doi: 10.1007/s11423-010-9154-5

[24] S. Rajić. Mathematics and music game in the function of child's cognitive development, motivation, and activity, Early Child Development and Care (2019), 1–13. doi:10.1080/03004430.2019.1656620.

[25] S. Manske, T. Hecking, I.-A. Chounta, S-Werneburg, H. U. Hoppe. Using difference to make a difference: a study on heterogeneity of learning groups Volume 1 of Exploring the Material Conditions of Learning: The Computer Supported Collaborative Learning (CSCL) Conference, The International Society of the Learning Sciences, Gothenburg, 2015.

[26] J. Feine, U. Gnewuch, S. Morana, A. Maedche. A taxonomy of social cues for conversational agents, International Journal of Human-Computer Studies 132 (2019),138–161. doi:10.1016/j.ijhcs.2019.07.009.

[27] A. M. Sinatra, K. Pollard, B. Files, A. Oiknine, M. Ericson, P. Khooshabeh. Social fidelity in virtual agents: impacts on presence and learning, Computers in Human Behavior 114 (2021). doi:10.1016/j.chb.2020.106562.

Competency model for open data literacy in professional learning within the context of Open Government Data (OGD)

Eugenia Loría-Solano, Juliana Elisa Raffaghelli
Universitat Oberta de Catalunya, Barcelona, 08018, Spain

Abstract
Research on Open Government Data (OGD) use reveals that the data is not being used as expected. Many governments have opened their data but lack the development of the capacities required for OGD usage. There is a need of having frameworks of reference for open data literacy (ODL). The initial screening of the literature uncovers there is a dearth of systemic interventions to develop ODL, and there is limited research on what works. This research will focus on understanding the contexts and barriers of OGD use to study the role of technical and critical data literacy concerning the current low usage. It will map practices to develop the ODL and expert's knowledge to create an instrument that could be applied for the diagnostic baseline of ODL. Also, it will explore the applicability of such an instrument for the self-analysis and external learning recognition on ODL. This model can be used in the sphere of government, universities, and business, to assess the level of competencies in OGD usage in their employees or students, and to identify ODL competencies' gaps in a different context of professional practice.

Keywords[1]
Open government data, open data usage, open data literacy, critical data literacy, technical data literacy, professional learning.

1. Introduction

The open data movement is an emerging political and socio-economic phenomenon that promises to promote civic engagement and drive public sector innovations in various areas of public life [1]. The Open Data Handbook (https://opendatahandbook.org/guide/es/what-is-open-data/) defines open data as data that can be freely used, reused, and redistributed by anyone, subject only, at most, to the requirement to attribute and share equally.

The open data initiative initially arises from the universal declaration on human rights of 1948, where the right to information is already mentioned in Art.19 (https://www.un.org/en/about-us/universal-declaration-of-human-rights). Along the same lines, the Open Knowledge Foundation, established in 2004, is recognized for its mission of "a just, free, and open future, where all non-personal information is open and free for all to use".

Open data has great potential for use, specifically, Open Government Data (OGD) for the development of public policies, democratic dialogue, entrepreneurship, among others [2].

There are many benefits expected with the opening of government data to citizens and companies, such as improving transparency, reliability in administration, promoting public participation and public-private collaboration, as well as revitalizing the economy, with the recognition that public data is assets of people. [3].

However, while many open databases are available, only a limited number of them are used [2], their active use is still limited because of issues with data quality and linkage [4]. In addition, for the use of open data, users require a framework of open data literacy skills

[1] Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: eloria@uoc.edu (A. 1); jraffaghelli@uoc.edu (A. 2).
ORCID: 0000-0003-1957-420X (A. 1); 0000-0002-8753-6478 (A. 2).

essential for advanced use of data in each context. Raffaghelli [6] has stated that reference frameworks are needed for educators' data literacy since after reviewing the literature corpus it was detected that data literacy connected to OGD is never considered in the adult´s data literacy educational frameworks even though it is a crucial dimension of educators' professional competence.

The expected outcomes and significance of this Ph.D. research are to identify a set of skills and knowledge required to perform in an advanced level of usage of open government data, thus finding the dimensions of ODL. As well as the development and deployment of a measurement instrument to assess the level of ODL capacities for the quantification of progress on ODL.

2. Justification

The relevance of this research relates the need of having a set of skills of reference for data literacy overall and for open data literacy, specifically.

Data literacy, as a research topic, stems from numeracy and statistical literacy. However, the most recent developments connect data literacy with data-driven digital environments [6]. The research tries to identify the needed skills and knowledge concerning professionals and adults in relation to open data. Open data is indeed a digital resource that can both trigger learning or be a product of formal, non-formal and informal learning. In this regard, Open Data can be deemed part of technological environments and has the potential to enhance learning.

As it appears from our initial screening of the literature, there is a dearth of systemic interventions to develop data literacy, and there is limited research on what works, as initiatives face funding and organizational challenges limit scaling up training [7].

According to Khayyat and Bannister [8], OGD field experiments such as hackathons and competitions continue to be conducted, but there has been no systematic research on the factors that contribute to a vibrant and sustainable ecosystem of co-creation with civil communities.

This research is intended to contribute to creating an instrument that allows the identification and assessment of open data literacy levels of knowledge. This tool can be used in the sphere of government, business and in universities, to recognize and measure the level of competences in open data usage in their employees or students in different contexts of professional practice.

3. Research problem

In the field of open government data, it is known that an effort was made to open data in many governments, but not so much has been done for the development of the necessary capacities for the exploitation or the optimal use of the same for the taking of government decisions. The World Bank recognizes that its current support models have focused more on data production and exchange than on building capacity to use data [9]. Furthermore, within the models developed for capacity building, only a few of them have been tested at scale [10]. For example, hackathons and local training activities within international cooperation such as Open Data Day (https://opendataday.org/). In the same line, one study of the use of the public sector data analytics in The Netherlands shows that the use of public sector data analytics requires developing organizational capabilities to ensure effective use, foster collaboration, and scale-up [11]. Due to the problem of the low use of open data, this research focuses on studying the open data literacy required for the effective and more frequent use of these by interested sectors including citizens.

3.1. Theoretical and empirical antecedents

Open Government Data is characterized by being data and information produced or commissioned by public bodies [12]. Broadly speaking, the OECD (https://www.oecd.org/) defines Open Government Data as "a philosophy, and increasingly a set of policies, that promote transparency, accountability and value creation by making government data available to all."

Citizens' participation in open government can improve their perceptions towards government as a transparent, participatory, and collaborative institution and such participation of citizens increases operational capacity and trust [13]. It promises other benefits such as greater accountability and increased public participation, but few of these initiatives have been evaluated in terms of their implementation and results.[14]. And while many open databases are available, only a limited number of them are used [2].

A decade has passed since the first International Data Conference (https://opendatacon.org/), which is designed to bring the global open data community together to learn, share, plan and collaborate on the future of open data and data for development. Although efforts have been made to open government data in many countries of the world, there has not been a similar effort to develop the necessary capacities for the use of data by citizenship.

Publishing OGD can lead to innovation since it allows external parties to access, explore and handle OGD, which in turn will help to develop and build useful services, products, and applications for the benefit of society [15]. However, Bonina & Eaton [16] state in their research on the governance of the ecosystems of Government Open Data (OGD) platforms, that after a decade of open data initiatives few economic and social benefits have been achieved due to incomplete or low-quality data, mismatches between the data that are needed and those that are published, and the existence of technical barriers to participation, besides lack of skills and training of users.

The use of open data, "is the activity that a person or organization performs to see, understand, analyze, visualize or in other ways use a set of data that a government organization has provided to the public" [2]. This definition of use can be identified as technical literacy in open data, delimited in this research as the competencies, knowledge, and skills necessary to download, clean, order, analyze and interpret open data in a specific context. Just publishing raw data, may not result in transparency, as without formatting the data may not be easy for most people to understand and use [17]. Some authors suggest helping users using visuals, "geovisualizing open data seems the next logical step to put open data in the hands of citizens" [18]. Since it is required the development of competencies for the effective use of public sector data analytics in the organizations [19]. Finally, Kassen [20] states that the reuse or processing of open data to develop third-party applications and projects requires skilled enthusiasts and tech-savvy citizens who are willing to contribute their time, knowledge and expertise to the creation or co-creation of products based on open data.

However, this technical definition of open data literacy focuses on technical skills. Another conception, critical data literacy, refers to the skills, knowledge, and attitudes to review the meaning of concepts, visualizations and operations carried out with the data that can put user groups at risk of inequity or ethical aspects.

"The value of openness in the fight against inequality should be emphasized, the equity should be placed at the center of data analysis, and practitioners should actively promote reflection on inclusion gaps in data and the harm those gaps can bring" [7].

"Data literacy is not just about open data, but open data can be an invaluable asset for inclusive and empowering data literacy development programs" [10]. Identifying the open data literacy framework and user skill gaps is crucial to understanding the types of professional learning contexts in which they can be developed. Montes and Slater [7] claim that the lack of a coherent and generally accepted definition of data literacy and requisite skill set leaves us without a real quantification of progress on open data literacy.

Theoretical frameworks refer to the critical theory and the socio-technical theory [21], applied to the studies on digital data, data-driven practices and their impact on society and education. Indeed, data literacy has become an essential part of digital competence as outlined in the DigComp Framework 2.1 [22]. Also, a critical approach to data is needed in an increasingly contested approach to the developments of data-driven practices [23].

The Data Skills Framework developed by the Open Data Institute (ODI) (https://theodi.org/article/data-skills-framework) is an initial reference for the technical data literacy approach. Also, in the Digital Competence Framework released by the European Commission (https://op.europa.eu/en/home), the concept of data literacy was introduced in 2017 alongside the information literacy dimension as an ability to search, read, and interpret data in several daily and academic contexts of communication [24].

On the other hand, critical data literacy will be studied in the light of the Data feminist principles developed in the book *Data Feminism*, which presents a new way of thinking about data science and data ethics, which is grounded in intersectional feminist thought. It debates about power, and how those differentials of power can be challenged and changed [25]. Likewise, other texts with a critical approach to data will be used as a frame of reference, such as Taylor [26] where the author posits that "just as an idea of justice is needed in order to establish the rule of law, an idea of data justice – fairness in the way people are made visible, represented and treated as a result of their production of digital data – is necessary to determine ethical paths through a datafying world".

Further frameworks to be studied are Markham (https://futuremaking.space/critical-pedagogy-data-literacy/) who characterizes critical pedagogy as a vital part of building data literacy. The author identifies it as a research stance that can challenge quantification, datafication, and computational logic and it moves beyond the level of data critique to social action in response to datafication. Other approaches will be considered such as Raffaghelli [27], where the author provides a conceptual scheme to address further pedagogical reflection and practice to support social justice against datafication.

4. Aim of the research

The aim of this research is to identify a model of the open data literacy that professional learners must acquire to operate in advanced contexts of data usage. Once detected through the model, such literacy could be developed through different types of learning contexts. Moreover, the model could address professional learning recognition.

The research aims at developing an instrument that allows recognition and assessment of several levels of competence in open data literacy. Therefore, the stage of skills and knowledge within a context of usage of open data as digital resources.

This is an original purpose since most studies analyze data literacy centered in technical procedures relating data science abilities [6] but miss the political contexts and the critical approach to data [17].

This instrument can be used in the sphere of government, business, and universities, to assess and recognize the level of competences in open data usage in their employees or students. Also, to identify and understand the OGD competences' gap in different contexts of professional practice.

Specific Objectives of this research:

1. To analyze current academic literature review to uncover the issues preventing open data usage, and within them, the role played by data literacy.
2. To identify what data literacy educational practices are currently available on the web there will be applied a mapping procedure of such pedagogical practices.
3. To validate such open data literacy dimensions by a panel of subject matter experts' interviews.
4. To build and develop the measurement instrument.
5. To theoretically validate the instrument by determining the validity of the tool through the Delphy method.
6. To empirically validate the instrument through Circulation of the instrument as a survey, the estimation of Cronbach's alpha statistic and the confirmatory factor analysis.
7. To test the instrument in the context of ecological learning training by the application of it to the participants, as well as the application of a statistical analysis of the results to determine a diagnostic baseline in Open Data literacy and sensitivity to competence change.

5. Research hypothesis

The evaluation and recognition of skills and knowledge connected to open data usage could be supported by an open data literacy tool.

6. Research questions

In this context, the following research questions have been posed:

RQ1 What are the contexts of use and learning based on OGD?

RQ2 What are the barriers that prevent the use of open data, and within those barriers, what role does technical and critical data literacy in open data play as one of the causes of the low use of OGD?

RQ3 What are the current pedagogical practices available that can be used to develop the ODL required to make use of OGD?

RQ4 What is the set of skills needed in OGD practice contexts required for professional learning?

RQ5 How should be configured a measurement instrument that could be applied for the diagnostic baseline of ODL?

RQ6 What is the applicability of such instrument for the self-analysis and/or external learning recognition on Open data literacy?

7. Methods

7.1. Design of research

To pursue the objective of this study, a mixed methods research approach will be applied. The design implies three phases to cover the objectives.

The **first phase** will be devoted to the analysis of the problem and the existing corpus of research. To this regard, a systematic review of the literature will be undertaken based on the methodological workflow called PRISMA [27] and it is a transparent report of systematic reviews and meta-analyzes. This method attempts to control for investigator bias in data collection and analysis [28].

The main PRISMA steps that will be carried out in this research are: 1. Select scientific databases, 2. Search the databases with keywords of interest for several articles, 3. Select articles using predefined exclusion criteria based on in the research objectives. 4. Analyze the selected articles by reading them in full.

The systematic review of the literature will be integrated with an analysis of existing pedagogical practices (benchmarking study/desk research), which will support the analysis of type of competences focused and trained as part of an underlying ODL approach.

Based on this selection, quantitative analysis methods will be applied that allow better identification of emerging issues and problems in a general and specific way, with respect to the research questions posed.

Also, an exploratory research, mapping and gap analysis is going to be performed to identify what data literacy educational practices are currently available in the web.

Finally, there will be a panel of experts interviews to identify dimensions as a base to the development and operationalization of the measurement instrument.

The **second phase** will be devoted to the development of a self-reported measurement instrument, over the basis of the theoretical assumptions emerging from the literature review.

After identification of the dimensions, from the theoretical frameworks review, for the theoretical validation, a Delphi study will be conducted. The panel of experts is going to be used for building the open data literacy set of skills and knowledge and the Delphi method to validate the measurement instrument. The Delphi method is defined as "a panel communication technique by which researchers collect expert opinions, enable experts to communicate anonymously with one another and then explore the underlying information collected" [29].

The panel of experts will be invited to review the instrument through the technique of interviews, developed in two stages. Therefore, the results will be assembled, and a second cycle of consultation will be enacted. [30]. A measurement instrument is going to be designed and created to assess open data literacy in the contexts of OGD. As for the empirical validation of the instrument, it is going to be circulated as a questionnaire to professionals working in either public administration or industry with a stratified sampling design by sector.

The study is going to use the exploratory, descriptive, and explicative approaches in its different research phases.

Finally, the **third phase** will be devoted to the instruments' consolidation and further validation in ecological training contexts, the developed scale will be applied in specific educational context to analyze the applicability to:

1. Evaluate the development of ODL in ecological training context.
2. Self-assess ODL in formal (undergraduate) and non-formal/informal (professional) learning contexts.

3. Recognize ODL in professional contexts.

7.2. Sample

7.2.1. First phase

The sample units will be the articles selected for the literature analysis. For the selection of articles, this research will apply the PRISMA method for the systematic literature review. The detail of what will be done in each step, for the selection of a sample of articles, is detailed below:

1. Selection of Databases. SCOPUS, DOAJ and WOS will be selected to perform the bibliographic search.
2. Selection of articles using keywords. It is of interest to this research to know characteristics related to the use of open data, as well as to know aspects that prevent its use. Therefore, the following keywords will be searched in the selected databases:
3. SCOPUS and DOAJ: (open AND data) AND (government) AND (us *)
4. WOS: (open AND data) AND (government) AND (usa *)
5. Screening of articles abstracts will be read, and the following exclusion criteria will be used:
   a. Date before 2016, to have the latest knowledge on the topic of interest
   b. DOI absence
   c. Other Open Data issues that are not OGD
   d. It is not an article or review
   e. Not in English
   f. Related to OGD but not its use
   g. Not available
6. Analysis of the articles after reading them in full: each one will be read completely and will be coded and classified in variables defined in the codebook, which will be defined by the authors based on the objectives of the research, to generate a database of articles that will later be analyzed quantitatively to obtain their respective findings. Specifically, the articles will be coded and classified in the following categories:
   a. The identity of the research (Authors, Title, Year, Title of the source, No. of Citations, DOI, Type of Document, Abstract of the article, Author's keywords)
   b. The research focuses on the type of open data and applications (Discipline, Type of Open Data, Applications of open data)
   c. Types of learning generated and barriers of use (Types of learning generated using open data, Barriers that prevent the use of open data)

Finally, after consolidating the categories, the authors will analyze 10% of the total set of articles and the agreement between evaluators will be estimated using Cohen's Kappa statistic (https://www.statisticshowto.com/cohens-kappa-statistic/). A kappa higher than 0.60 can be considered a good agreement.

7.2.2. Second phase

In the initial task relating to the Panel of experts' interviews and Delphi study, the expert selection will be carried out in a non-random manner based on their expertise on the phenomenon being studied [31]. In this case are OGD subject matter experts. The sample size for the interviews and the Delphi study will be determined by the saturation point with a minimum of seven qualitative interviews to subject matter experts, active OGD users.

The target population is made up by 1. Quantitative units of analysis are current and potential OGD users around the globe that are available to fill out the instrument, 2. Qualitative units of analysis: are adult professionals identified as subject matter experts, and frequent users of OGD and ORD. Specifically, to test the questionnaire and to get data to validate and measure the reliability of the questions. The experts are professionals who have high experience on OGD usage. Professionals are current or potential users of OGD.

The sample size estimated for this study is 196 units of analysis, therefore 196 OGD users. It assumes a confidence level of 95%, a maximum error of 7% and a variance of 0.25. It assumes a big target population of ODG users.

Since currently there isn´t defined a sampling frame of the OGD user´s population, the type of sampling to be used in this study is non-probabilistic sampling defined as “a sampling technique in which some units of the population have zero chance of selection or where the probability of selection cannot be accurately determined” [31].

Measures of construct reliability and validity will be implemented, over the basis of classical test theory [32], [33].

7.2.3. Third phase

Two groups will be tested:

1. A group with at least 20 workers with none to high experience on the usage of OGD in both public and industry settings, for self-assessment and recognition of competences purpose.
2. A group of at least 20 undergraduate students in several disciplines, for self-assessment purposes, will be experimentally exposed or not exposed to OGD.

7.3. Data collection techniques and instruments

For data collection the research will adopt a mixed methods approach. A desk research approach will be applied to the first phase will adopt documental analysis and classification of pedagogical practices through a deductive scheme of analysis. Also, a synthesis report will be performed to identify ODL set of skills to define its dimensions. Then, in the second phase, a qualitative approach based on in-depth interviews will be adopted for the identification of dimensions and the instrument design and Delphi study for theoretical validation.

On the other hand, a quantitative approach will be adopted both for the instrument empirical validation (end of the second phase), and for the instrument testing (third phase). An electronic form with the instrument will be implemented and circulated for data collection. In the case of the third phase, there will also be a qualitative data collection and analysis. Indeed, the instrument will be embedded in a learning management system and the results will be made available for the respondents to react, reflect, and discuss upon them as the formative impact of the instrument implementation.

7.4. Procedure

The procedure is going to be developed in three phases, as explained before, and it is summarized in table 1, which is located at Appendix 1. The summary table includes the phase, objective that is going to be pursued, the activity or task to be performed, the method to be applicable for pursuing the objective and the expected output or result for each task.

8. Current status and results

8.1. Systematic review of literature

In short, the PRISMA systematic review of literature reveals that the use of OGD seems to depend largely on the necessary technical and critical skills. Although there are many technological, structural, organizational, and cultural barriers, the skills of the stakeholders to use and obtain the expected benefits of open data is an obstacle that requires consideration.

The analysis of the corpus of literature uncovers that the lack of open data literacy arises as the main barrier, particularly in social sciences, OGD and governance. Our results reinforce the importance of data literacy, this is coherent with Matheus & Janssen [17] who imply that the same data that creates a higher level of transparency for the expert, creates less for someone with lack of knowledge of how to use it. re being considered.

Overall, what can be inferred from our analysis is that literacy opportunities are mostly technical; and that engagement with open data, when occurs, produces meaningful learning.

However, our analysis could not cover to what extent the collaborative and co-creative synergies between stakeholders can lead to innovation and governance. These are aspects that remain to be studied towards a holistic and critical data literacy.

Finally, the research outputs at this stage of the PhD are part of a literature review research, but the following phases relate online observations, interviews, the construction of an instrument based on a survey and the empirical validation in two phases.

9. Limitations of the study

This research is at a very early stage. In any case, the limitations foreseen relate a) the documented difficulties in analyzing adult learning and identifying patterns of learning activity (most learners follow informal learning pathways); b) the complex approach that the empirical validation will require, in terms of participants' recruitment; c) the complexity of identifying experts and contexts for empirical work.

In any case, risk management strategies are being considered.

10. Data management and ethics

This research plan was approved by the ethics committee of the UOC. For the approval of the ethical form, it was required to explain details about data curation policies, informed consent, how to proceed with the database once the study is concluded, etc. The data will be processed exclusively for the purposes for which they have been collected and for the time strictly necessary to fulfill the purposes for which they will be collected.

11. Acknowledgements

We would like to acknowledge UOC's doctoral school on Education and ICT program, which offers the courses of social research design, Research methods, Directed Research subjects, as well as, workshops, and training sessions, during which we have been able to develop this research proposal.

12. References

[1] M. Kassen, "Understanding motivations of citizens to reuse open data: open government data as a philanthropic movement," Innovation, vol. 00, no. 00, pp. 1–27, 2020, doi: 10.1080/14479338.2020.1738940.

[2] A. Zuiderwijk, M. Janssen, and Y. K. Dwivedi, "Acceptance and use predictors of open data technologies: Drawing upon the unified theory of acceptance and use of technology," Gov. Inf. Q., vol. 32, no. 4, pp. 429–440, Oct. 2015, doi: 10.1016/j.giq.2015.09.005.

[3] T. Sumitomo and N. Koshizuka, "Progress and Initiatives for Open Data Policy in Japan," Computer (Long. Beach. Calif)., vol. 51, no. 12, pp. 14–23, Dec. 2018, doi: 10.1109/MC.2018.2879993.

[4] K. Haklae, "Interlinking Open Government Data in Korea using Administrative District Knowledge Graph," J. Inf. Sci. Theory Pract., vol. 6, pp. 18–30, 2018, doi: 10.1633/JISTaP.2018.6.1.2.

[5] J. E. Raffaghelli, "Developing a framework for educators' data literacy in the European context: Proposal, Implications and debate.," in International Conference on Education and New Learning Technologies EDULEARN, Jul. 2019, pp. 10520–10530, doi: 10.21125/edulearn.2019.2655.

[6] J. E. Raffaghelli, "Developing a framework for educators' data literacy in the European context: Proposal, Implications and debate." in EDULEARN19 Proceedings, 2019, vol. 1, doi: 10.21125/edulearn.2019.2655.

[7] M. G. Montes and D. Slater, "Issues in open data: Data literacy. In T. Davies, S. Walker, M. Rubinstein, & F. Perini (Eds.)," in The state of open data: Histories and horizons, Cape Town and Ottawa: African Minds and International Development Research Centre, 2019, pp. 274–286.

[8] M. Khayyat and F. Bannister, "Towards a model for facilitating and enabling co-creation using open government data," Inf. Polity, vol. 22, no. 4, pp. 211–231, Nov. 2017, doi: 10.3233/IP-170406.

[9] World Bank, "Data for Development An Evaluation of World Bank Support for Data and Statistical Capacity," 2017. Accessed: Apr. 19, 2021. [Online]. Available: www.worldbank.org.

[10] T. Davies, S. Walker, M. Rubinstein, and F. Perini, The State of Open Data: Histories and Horizons. Cape Town and Ottawa: African Minds and International Development Research Centre, 2019.

[11] Van Veenstra and Gromme, "(6) (PDF) The Use of Public Sector Data Analytics in The Netherlands," Sep. 2020. https://www.researchgate.net/publication/344202992_The_Use_of_Public_Sector_Data_Analytics_in_The_Netherlands (accessed Jan. 03, 2021).

[12] B. Ubaldi, "Open Government Data: Towards Empirical Analysis of Open

Government Data Initiatives," OECD Work. Pap. Public Gov., vol. NO.22, no. 22, p. 61, 2013, doi: 10.1787/5k46bj4f03s7-en.
[13] L. Schmidthuber, F. Piller, M. Bogers, and D. Hilgers, "Citizen participation in public administration: investigating open government for social innovation," 2019.
[14] R. Sandoval-Almazan and J. R. Gil-Garcia, "Toward an integrative assessment of open government: Proposing conceptual lenses and practical components," J. Organ. Comput. Electron. Commer., vol. 26, no. 1–2, pp. 170–192, Apr. 2016, doi: 10.1080/10919392.2015.1125190.
[15] M. Saleh Altayar, "Motivations for open data adoption: An institutional theory perspective," 2018, doi: 10.1016/j.giq.2018.09.006.
[16] C. Bonina and B. Eaton, "Cultivating open government data platform ecosystems through governance: Lessons from Buenos Aires, Mexico City and Montevideo," Gov. Inf. Q., vol. 37, no. 3, p. 101479, Jul. 2020, doi: 10.1016/j.giq.2020.101479.
[17] R. Matheus, M. Janssen, and D. Maheshwari, "Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities," Gov. Inf. Q., vol. 37, no. 3, p. 101284, Jul. 2020, doi: 10.1016/j.giq.2018.01.006.
[18] A. Degbelo, J. Wissing, and T. Kauppinen, "A comparison of geovisualizations and data tables for transparency enablement in the open government data landscape," Int. J. Electron. Gov. Res., vol. 14, no. 4, pp. 39–64, Oct. 2018, doi: 10.4018/IJEGR.2018100104.
[19] A. F. van Veenstra, F. Grommé, and S. Djafari, "The use of public sector data analytics in the Netherlands," Transform. Gov. People, Process Policy, 2020, doi: 10.1108/TG-09-2019-0095.
[20] M. Kassen, "Adopting and managing open data," Aslib J. Inf. Manag., vol. 70, no. 5, pp. 518–537, Sep. 2018, doi: 10.1108/AJIM-11-2017-0250.
[21] T. Fenwick, M. Nerland, and K. Jensen, "Sociomaterial approaches to conceptualising professional learning and practice," J. Educ. Work, vol. 25, no. 1, pp. 1–13, Feb. 2012, doi: 10.1080/13639080.2012.644901.
[22] S. Carretero, R. Vuorikari, and Y. Punie, "The Digital Competence Framework for Citizens With Eight," Publ. Off. Eur. Union, no. May, p. 48, 2017, doi: 10.2760/38842.
[23] B. Williamson, "Journal of Education Policy Digital education governance: data visualization, predictive analytics, and 'real-time' policy instruments," 2015, doi: 10.1080/02680939.2015.1035758.
[24] J. E. Raffaghelli, "Is data literacy a catalyst of social justice? A response from nine data literacy initiatives in higher education," Educ. Sci., vol. 10, no. 9, 2020, doi: 10.3390/educsci10090233.
[25] C. D'Ignazio and L. F. Klein, Data Feminism. 2020.
[26] L. Taylor, "What is data justice? The case for connecting digital rights and freedoms globally," Big Data & Society July–December 2017, 2017. https://pure.uvt.nl/ws/portalfiles/portal/26363266/taylor_17_what_is_data_justice.pdf (accessed May 09, 2021).
[27] A. D. Moher D, Liberati A, Tetzlaff J, "PRISMA 2009 Flow Diagram," The PRISMA statement, vol. 6. 2009.
[28] M. Petticrew and H. Roberts, Systematic Reviews in the Social Sciences: A Practical Guide. 2006.
[29] Y.-F. Yeh, Y.-S. Hsu, H.-K. Wu, F.-K. Hwang, and T.-C. Lin, "Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the Delphi survey technique," Br. J. Educ. Technol., vol. 45, no. 4, pp. 707–722, 2014, [Online]. Available: https://www.learntechlib.org/p/148366/.
[30] M. Adler and E. Ziglio, Gazing into the oracle: the Delphi method and its application to social policy and public health. Jessica Kingsley Publishers, 1996.
[31] A. Bhattacherjee, Social Science Research: Principles, Methods, and Practices, 3rd ed. Textbooks Collection., 2012.
[32] P. Mair, Modern Psychometrics with R. Cham: Springer International Publishing, 2018.
[33] T. A. Kyriazos and A. Stalikas, "Applied Psychometrics: The Steps of Scale Development and Standardization Process," Psychology, vol. 09, no. 11, pp.

2531–2560, 2018, doi: 10.4236/psych.2018.911145.

13. Appendix 1

Table 1
Procedure summary table

Phase	Objective	Activity	Method	Expected Result
Phase 1	Analysis of the problem and the existing corpus of research and to map current pedagogical practices	Academic literature review	Systematic literature review with the PRISMA Method	ODL centrality needs and the identification of professional learning needs.
		Mapping of pedagogical practices	Desk work and benchmarking	Map of current pedagogical practices and gap identification
		Report of skills and knowledge required for open data literacy	Synthesis report	Identification of sets of skills and knowledge to be included in the instrument.
Phase 2	To develop and validate the measurement instrument	To establish and validate the dimensions of ODL construct	Panel of experts (interviews)	Established ODL Dimensions
		Instrument development	Operationalization of the dimensions in Items with Likert scale	Questionnaire prepared in document and digital
		To validate dimensions of ODL by experts	Delphi Method	Validated ODL Dimensions
		Empirical validation of the instrument	Circulation of the instrument as a survey to a population of at least 196 persons	First report of the empirical validation analysis
		Definitive validation of the instrument	Cronbach's Alpha Estimation and Confirmatory Factor Analysis	Instrument validation report
Phase 3	To use the instrument in a context of ecological learning	Testing the instrument in a context of ecological learning training	Application to the participants of an ecological training context	Report of results of the instrument that includes baseline of diagnosis and sensitivity to change of competence.
			Statistical analysis of the results of the instrument to determine a diagnostic baseline in Open Data literacy and sensitivity to competence change.	Measurement instrument released.

Using epistemic information to improve learning gains in a computer-supported collaborative learning context

Max Dieckmann, Davinia Hernández-Leo

Universitat Pompeu Fabra (UPF), Plaça de la Mercè, 10-12, 08002 Barcelona

Abstract

Computer-supported collaborative learning (CSCL) is a method in education where the students work together on a task while the teacher takes on the role of a coach who --- aided by information technology --- scaffolds their progress and allows them to discover a solution on their own. CSCL exercises are often run following a script, which breaks the activity in a set number of steps to facilitate productive collaboration. This makes it easier for the teacher to orchestrate the exercise --- controlling the flow of the activity and attending to the students' needs as they arise. Teacher-facing dashboards are often used to enable orchestration by providing information about and controls to manipulate the state of the activity. Our research is centered on analyzing whether teachers and students can benefit from visualizing epistemic information, i.e. learning analytics data derived from examining the content of students' input. We expect that giving teachers access to epistemic information will facilitate orchestration, reduce the cognitive load required to oversee a CSCL activity, and create the opportunity for teacher-led debriefing --- a technique used by educators to make students reflect on the activity they engaged in and thus help them get a deeper understanding of the content that was covered. We also expect that this will ultimately have a positive impact on students' learning gains. We will extend the dashboard of “PyramidApp” --- a software tool that implements the CSCL “Pyramid” script --- with epistemic information to test our hypothesis. Subsequently, we will analyze how our findings transfer to other CSCL scripts and tools. We thus hope to contribute to the existing knowledge of how learning analytics data can successfully be employed in a CSCL context. We will follow the design-based research method which emphasizes co-operation with teachers and aims to test and apply interventions in realistic scenarios.

Keywords 1

Computer-supported collaborative learning, orchestration, teacher-led debriefing, epistemic information, design-based research

1. Introduction

The idea of using computers in education dates back to the 1960s [1]. What was initially a fringe approach has become more and more common and shows no signs of slowing down [2]. Using this technology for teaching and learning has great appeal for both educational institutions and researchers. Subsequently, the field of *technology enhanced learning (TEL)* emerged and with it a plethora of studies. This is particularly evident since the beginning of the Corona-crisis, as many institutions were forced to conduct at least part of their lessons online [3]. While the actual impact of using technology for education has been criticized, the endeavor is still viewed as promising [4]. Another frequent criticism is that the results from the lab don't translate to the reality of the classroom --- or that they never make it there in the first place [5]. However, with further development comes further progress: Many

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: max.dieckmann@upf.edu (M. Dieckmann); Davinia.hernandez-leo@upf.edu (D. Hernández-Leo)
ORCID: 0000-0001-7128-8337 (M. Dieckmann); 0000-0003-0548-7455 (D. Hernández-Leo)

researchers place an emphasis on developing and testing their interventions in realistic scenarios and are adding to the growing amount of evidence that enhancing learning through technology is not only possible, but worthwhile.

Learning analytics is a fast-growing area of *TEL* and is defined as “the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs” [6]. Typically, *learning analytics* data is automatically collected and processed by machines. One benefit of this approach is that large amounts of data can be handled and made use of --- potentially in real time.

Another relatively modern trend in education is collaborative learning [7]. This means that the students will work together on a task and try to find a solution, rather than being directly told how to get there. The role of the teacher becomes that of a coach, who scaffolds the students’ progress rather than giving them the correct answers / techniques outright. This is also referred to as “guided participation”. There are many forms of collaborative learning, but the most effective approaches seem to be those that put a focus on intrinsic incentives (e.g. the student’s natural search for knowledge, competence, and stimulating communication) and frame the task in a way that emphasizes collaboration rather than competition. The positive effects of this method are most notable when looking at conceptual insights that are acquired by the students --- something that is notoriously difficult to teach. However, collaborative learning is no more successful than direct instruction when teaching formulas, procedures, or the application of an existing model.

Computer supported collaborative learning (CSCL) is the combination of collaborative learning and *technology enhanced learning* [2, 8, 9, 10]. It has the potential to solve some of the problems that arise when implementing a collaborative learning task and has seen a lot of activity in the last decades. Unlike in direct instruction, the teacher's attention is split among several groups, which will likely work at different paces and struggle at different times. In order to manage this demand, a *CSCL* activity will often be run following to a *CSCL* script which scaffolds [11] the students and provides a clear pattern to follow [12]. One of the main benefits of using computer technology in a *CSCL* context is that the scripted activity can be automated, reducing organizational overhead and in many cases making it possible to implement an exercise that would not be possible otherwise. There are indications that this is beneficial to students by increasing their motivation, shaping their expectations and freeing up time to focus on the task.

While a *CSCL* script gives the task a clear structure --- with all the upsides that such a guide brings ---, technology can help make its implementation more flexible to its specific context. This is described by the notion of orchestration: The teacher needs to respond to the students' needs as they arise and adapt the exercise to the current situation [13, 14]. Computer technology can provide the teacher with data that they can use to better orchestrate the activity or gain valuable information they can use to prepare future lectures. This is often done in the form of a teacher-facing dashboard, where the teacher can control the state of the exercise. Common use cases are pausing the activity to clear up misconceptions or motivate non-participating students, skipping unnecessary waiting time when moving on to the next stage, and identifying and scaffolding struggling groups.

There have been several implementations of teacher-facing dashboards that visualize learning analytics data. Our focus will be on the visualization of epistemic information derived from analyzing the content of the students' inputs (answers, chat messages etc.). We expect that visualizing synthesized epistemic information can reduce teacher cognitive load as it drastically reduces the amount of text a teacher has to read to follow the students' progress. Additionally, we expect this to have a positive impact on orchestration by making it easier to identify when and where to intervene, as well as to facilitate teacher-led debriefing by highlighting the most relevant student contribution for further discussion.

In teacher-led debriefing lectures, students' answers are put into perspective and addressed in the light of new course content. Students are required to justify their beliefs, receive

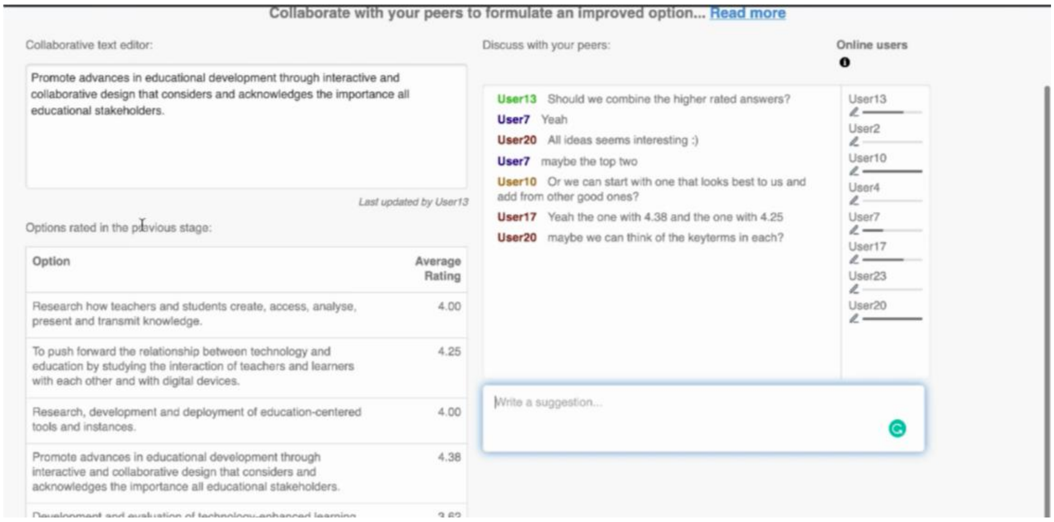

Figure 1: (Stage 3) Students collaborate in a group and agree on a collective answer.

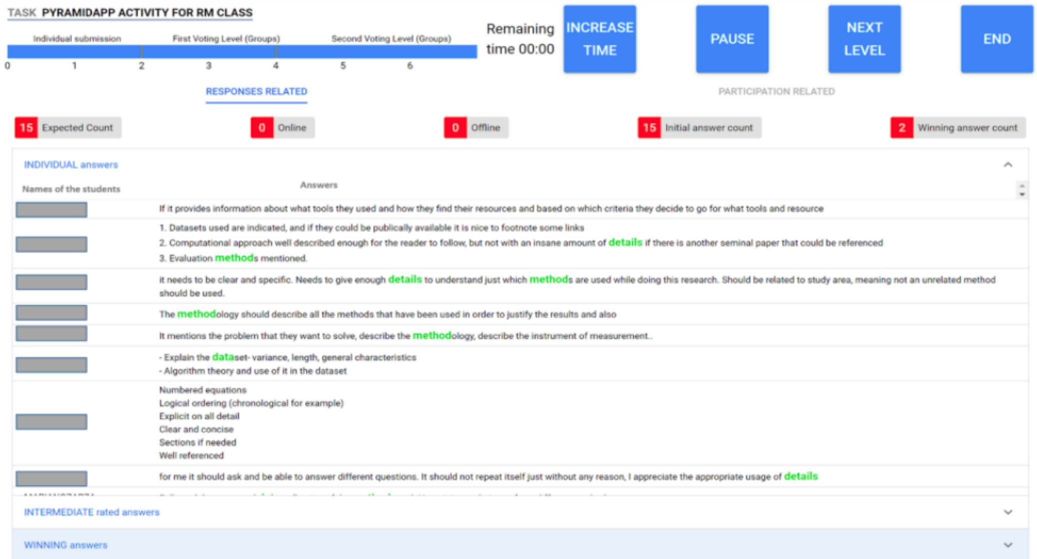

Figure 2: Part of the dashboard of the *PyramidApp*. The dashboard provides information and controls for orchestration to the teacher.

feedback on their performance and thus get to structure their newly acquired knowledge before integrating it into a theoretical framework [13, 15]. Similar techniques have already been successfully applied in simulation-based medical education, where it is considered to be an important component of the learning experience [16, 17].

We are basing the assumptions on the impact of our intervention in part on a study similar to our own, in which content analysis data was added to a teacher-facing dashboard to support the *CSCL* activity *EthicApp* [18]. The data visualizations were derived using *natural language processing (NLP)* techniques on student data, rank ordering comments by relevance and comparing the work groups by how homogeneous their members opinions are. Results were promising: Experts judged about 80% of the selected comments as viable, which indicates that this approach could be useful in reducing the number of comments teachers have to consider when monitoring an activity and thus reducing cognitive load.

The approach to use *NLP* technology to analyze students' artefacts and utterances for learning analytics is not without precedence and there are several techniques that seem promising [19, 20, 21]. One such technique is the analysis of text to gain a measure on the level of confusion and precision in the students' answers [22, 23]. Other studies showed the potential to investigate semantic similarity, sentiment, and point-of-view --- going as far as being able to gauge the degree of collaboration within a group that is working on a *CSCL* task [21, 24, 25].

Ultimately, we expect that the effects of our intervention will extend from the teachers to the students and have a positive impact on their learning gains.

2. Research context

An example of a *CSCL* script is the "Pyramid" (sometimes referred to as "Snowball"), which is structured as follows [26]:

The teacher will initially give a task to the students, usually to answer an open question. In the first stage, the students will each individually think about and write down their answer. In the second stage, they are presented with a selection of answers from their peers and rate these answers by what they think are the most correct and complete. In the third stage, the collaboration truly begins, as the students are assigned to groups where they discuss the previously rated answers and synthesize an answer for the group. Finally, the group answers are rated by all students and thus the class agrees on one final answer. Depending on the size of the class, stages 2 and 3 will be repeated with larger and larger groups, until a final consensus is reached.

Another example of a *CSCL* script is the "Jigsaw": First, students work on their own on one of several topics. Then, expert groups get formed by grouping the students by the topic that they worked on. In these groups, the students help each other understand their topic in depth and prepare to present it to non-experts. In the last phase, groups are formed heterogeneous by mixing students in a way that each group has at least one expert of each topic. They then take turns explaining what they are now proficient in to the non-experts until the whole group understands the entire range of topics.

PyramidApp is a software that implements the "Pyramid" script, making it easy to integrate it into a classroom lesson or online course [27, 28]. Figure 1 shows the group stage of a "Pyramid" script in *PyramidApp*. *PyramidApp* also comes with a teacher-facing dashboard, which provides information about the state of the activity and gives the teacher controls for orchestration (see Figure 2) [14].

We will initially focus on the "Pyramid" script and *PyramidApp*, but we are hoping to extend the research by analyzing to what extent the interventions that will be designed and evaluated are transferable to other *CSCL* scripts such as "Jigsaw" or "ArgueGraph" [29, 30].

3. Research questions

To sum up, the research questions that we want to answer are the following:

1. How can teacher-oriented dashboards with *learning analytics (LA)* indicators based on epistemic information facilitate teacher-led debriefing in *CSCL* scripts?
2. How can teacher-oriented dashboards with *LA* indicators based on epistemic information facilitate real-time orchestration in *CSCL* scripts?
3. Do teacher interventions informed by *LA* indicators related to epistemic information improve learning gains?

Section 1 covers the background and motivation of our questions, section 2 introduces a concrete implementation of a *CSCL* script that we will build upon to test our questions, section 4 lays out the methodology we will use to attempt to answer our questions, and section 5 concludes with describing what

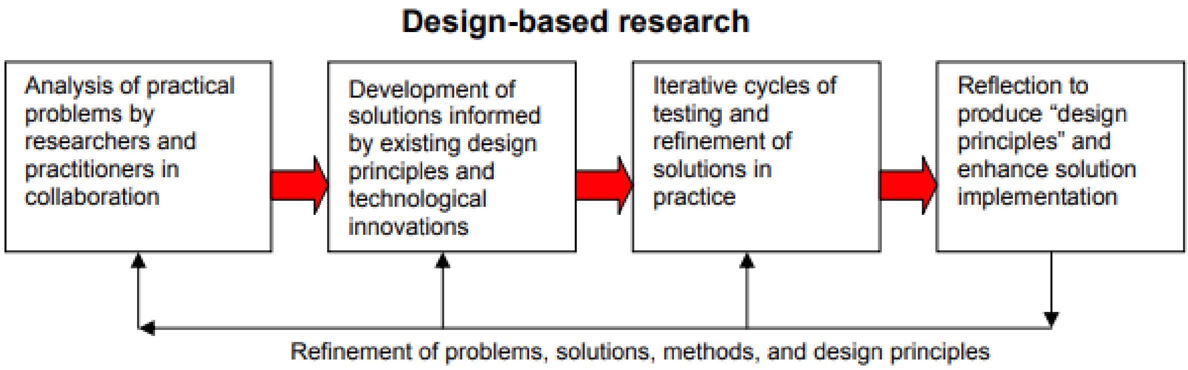

Figure 3: Overview of the *design-based research* method.

we expect the impact answering our questions will have.

4. Methodology & methods

Design-based research is a paradigm that aims to bring educational research back to where it has the most impact [5, 31]. Instead of separating the laboratory and the classroom, the researchers are collaborating with all stakeholders to make the research realistic and applicable. Interventions go through several design cycles, where the initial experiment will be refined and the results integrated into the underlying theory.

We are going to explore several approaches to gather and present epistemic information in the *PyramidApp* dashboard and implement the interventions in practice. We will use existing data from previous experiments with *PyramidApp* to analyze the feasibility of the different presentation approaches and co-design prototypes in cooperation with the stakeholders.

Following the *design-based research* methodology, the project will go through several cycles. Figure 3 shows the typical phases of each cycle (taken from [32]).

4.1. Analysis

In the analysis stage, we conducted a literature review and identified that providing epistemic information to the teacher during a *CSCL* activity could lead to improved orchestration and debriefing. We then gathered several ideas for possible ways in which epistemic information could be gathered (see Table 1) and integrated (see Table 2) into the *PyramidApp* dashboard. It should be mentioned that they are not mutually exclusive and we hope to be able to implement several of them simultaneously.

Before moving to the second stage (development), we will need to identify which of these options are the most promising in terms of feasibility and impact. To achieve this, we will analyze existing *PyramidApp* data that we have access to. This data comes from previous applications of *PyramidApp* in real classroom scenarios. It consists of all inputs made in the application, both from teachers (e.g. interactions with the dashboard) and students (e.g. answers and chat messages), as well as metadata such as timestamps. Some of the students' answers have also been rated by teachers, giving us additional information that

Collecting epistemic data		
Prompt the teacher to provide a sample answer and use that for comparison with students' answers.	Teacher rates some of the questions along with the students.	Teachers generate keywords by clicking them in the students' answers.
Measure confusion and precision in student's input using *NLP* [22, 23].	Compare semantic similarity of students' answers and teachers' answer using *NLP* [24].	Conduct sentiment analysis of students' input using *NLP* [25].

Table 1: Potential methods to collect epistemic data.

Using epistemic data		
Form groups based on epistemic factors such as the answer quality and participation level of the students.	Display engagement levels, i.e. whether students are discussing the topic at hand.	Knowledge graph, i.e. a network visualisation of connected and disconnected knowledge items [33].
Display the most representative comments / contributions [18].	Highlight the most informative words in students' answers (e.g. using *Term Frequency Inverse Document Frequency (TF-IDF)*) [34].	

Table 2: Potential methods to use epistemic data. Cell colors indicate whether the method has potential applications for orchestration (requires real-time display), teacher-led debriefing (displayed at the end of the activity) or both.

could help to automatically identify the quality of a student-submitted text. In some cases, we might also develop low-fidelity prototypes to gauge the technical feasibility of our ideas. Finally, we will create mock-up visualizations and seek feedback from teachers. This preliminary work should allow us to identify the most promising approaches and might lead us to discard or add ideas.

4.2. Development

In the development stage, we will now be able to make an informed decision on which and how many of the visualizations we want to implement and will begin by creating a low-fidelity, "proof-of-concept" prototype. We will seek feedback from colleagues and teachers and improve it until we have a first version that is sophisticated enough for a realistic test.

4.3. Testing

We will then enter the testing stage, where we intent to conduct multiple within-subjects experiments running a *PyramidApp* activity with and without epistemic information in a realistic classroom or *Massive Open Online Course (MOOC)* setting. This is the phase where we collect our data: we will use the *PyramidApp* software to automatically log all inputs of both students and teachers during the activity (the data we analyzed in stage one was collected in the same way in the past). We will also need to keep track of what was displayed in the dashboard at any time, ask experts to rate the students' answers, and have teachers and students answer questionnaires. We will consider using a dual-task method to directly measure teacher cognitive load [35]. If necessary, we will fix errors, improve the software and conduct additional tests until we have preliminary results.

4.4. Reflection

This data will then be analyzed in the reflection stage. We will attempt to integrate the findings into our understanding of the underlying theory and identify where things went well and where there were problems. We will reflect on the impact that our intervention had by comparing it to the activities where teachers did not have access to epistemic information. We expect to see a positive impact in the form of a measurable reduction in cognitive load, increase in the ease of orchestration, facilitation of teacher-led debriefing, and student learning gains.

When considering learning gains, it has to be kept in mind that giving a correct answer

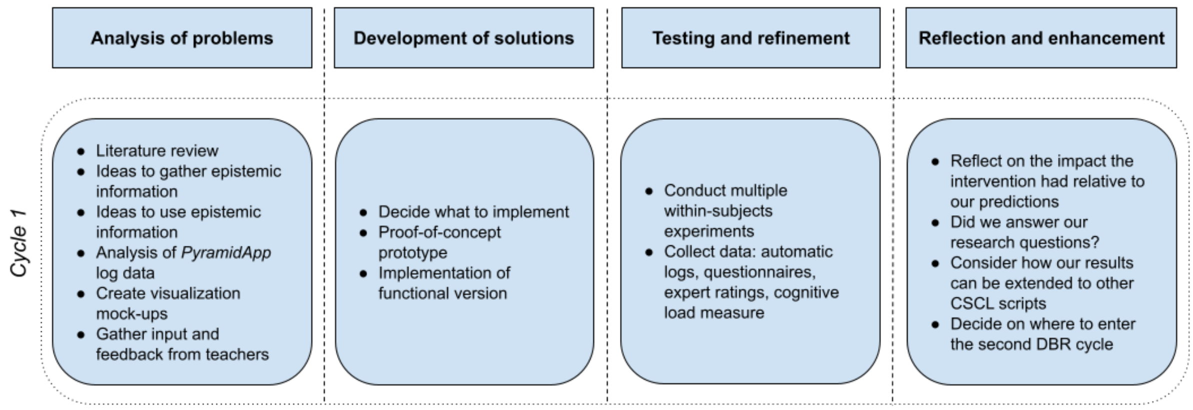

Figure 4: Planned first *design-based research* cycle for this project.

does not necessarily mean that one knows what they are doing, but measuring --- or even defining --- understanding is challenging [36]. We will focus on tangible expert scores for the time being, but might incorporate alternative measurements in the future.

We will then use all the insights that we've gained to begin the second *design-based research* cycle. We will ask ourselves whether the data we gather and analyzed was sufficient to confirm or deny our expectations and answer our research questions. We will consider what would be necessary to extend our results to other *CSCL* scripts. Our considerations will let us decide whether we need to run additional experiments, formulate new research questions, or further develop our epistemic data visualizations.

Figure 4 summarizes how the first *design-based research* cycle looks like for this project.

5. Conclusions

Following the *design-based research* philosophy, the ultimate goal of our research is the application of the findings in real teaching situations in a way that improves learning gains and / or reduces the workload of the people involved.

Our expected contribution is the development of visualizations of *learning analytics* data based on epistemic information to reduce cognitive load, support orchestration, and facilitate debriefing of *CSCL* scripts. We expect that this will improve learning gains and we will directly implement and validate it for the "Pyramid" script as well as critically examine and discuss its value for other types of *CSCL* scripts such as "Jigsaw" or "ArgueGraph".

The indirect influence of the research would be through the insights gained. The theory of the science of learning could be extended by getting valuable information on the effects and effectiveness of debriefing and orchestration in a *CSCL* context. Proving -- or disproving -- its impact can inform the direction of further research and lead to the development of successful interventions in the future.

It should not be forgotten that even a "negative" result would be significant, as it could suggest that a specific type of intervention is inferior and the time of educators is better spent elsewhere.

In this way, we hope to make a contribution to the further improvement of educational practice.

6. Acknowledgements

Thanks to Ishari Amarasinghe for providing me with ideas for ways in which epistemic information could be gathered and integrated into the *PyramidApp* dashboard.

7. References

[1] G. Paquette, Technology-based instructional design: Evolution and major trends, Handbook of Research on Educational Communications and Technology: Fourth Edition (2014) 661–671. doi:10.1007/978-1-4614-3185-5_53.

[2] H. Jeong, C. E. Hmelo-Silver, K. Jo, Ten years of computer-supported collaborative

learning: A meta-analysis of cscl in stem education during 2005–2014, Educational Research Review 28 (2019) 100284. doi: 10.1016/J.EDUREV.2019.100284.
[3] T. Surma, P. A. Kirschner, Technology enhanced distance learning should not forget how learning happens, Computers in Human Behavior 110 (2020) 106390. doi: 10.1016/J.CHB.2020.106390.
[4] A. Kirkwood, L. Price, Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? a critical literature review, Learning, Media and Technology 39 (2014) 6–36. doi:10.1080/17439884.2013.770404.
[5] F. Wang, M. J. Hannafin, Design-based research and technology-enhanced learning environments, Educational Technology Research and Development 2005 53:4 53 (2005) 5–23. doi: 10.1007/BF02504682.
[6] R. Ferguson, Learning analytics: Drivers, developments and challenges, International Journal of Technology Enhanced Learning 4 (2012) 304–317. doi: 10.1504/IJTEL.2012.051816.
[7] W. Damon, E. Phelps, Critical distinctions among three approaches to peer education, International Journal of Educational Research 13 (1989) 9–19. doi: 10.1016/0883-0355(89)90013-X.
[8] E. Lehtinen, K. Hakkarainen, L. Lipponen, M. Rahikainen, H. Muukkonen, Computer supported collaborative learning: A review, The JHGI Giesbers reports on education 10 (1999) 1999.
[9] P. Dillenbourg, S. Järvelä, F. Fischer, The evolution of research on computer-supported collaborative learning, Technology-Enhanced Learning: Principles and Products (2009) 3–19. doi: 10.1007/978-1-4020-9827-7_1.
[10] G. Stahl, T. Koschmann, D. Suthers, Computersupported collaborative learning, The Cambridge Handbook of the Learning Sciences (2014) 479–500. doi: 10.1017/CBO9781139519526.029.
[11] J. Hammond, P. Gibbons, What is scaffolding, Teachers' voices 8 (2005) 8–16.
[12] A. Weinberger, I. Kollar, Y. Dimitriadis, K. MäkitaloSiegl, F. Fischer, Computer-supported collaboration scripts, Technology-Enhanced Learning: Principles and Products (2009) 155–173. doi: 10.1007/978-1-4020-9827-7_10.
[13] P. Dillenbourg, P. Jermann, Technology for classroom orchestration, New Science of Learning: Cognition, Computers and Collaboration in Education (2010) 525–552. doi: 10.1007/978-1-4419-5716-0_26.
[14] I. Amarasinghe, D. Hernandez-Leo, K. Michos, M. Vujovic, An actionable orchestration dashboard to enhance collaboration in the classroom, IEEE Transactions on Learning Technologies 13 (2020) 662–675. doi: 10.1109/TLT.2020.3028597.
[15] P. Dillenbourg, F. Hong, The mechanics of cscl macro scripts, International Journal of ComputerSupported Collaborative Learning 2007 3:1 3 (2008) 5–23. doi: 10.1007/S11412-007-9033-1.
[16] J. W. Rudolph, R. Simon, D. B. Raemer, W. J. Eppich, Debriefing as formative assessment: Closing performance gaps in medical education, Academic Emergency Medicine 15 (2008) 1010–1016. doi: 10.1111/J.1553-2712.2008.00248.X.
[17] T. Levett-Jones, S. Lapkin, A systematic review of the effectiveness of simulation debriefing in health professional education, Nurse Education Today 34 (2014) e58–e63. doi: 10.1016/J.NEDT.2013.09.020.
[18] C. Alvarez, G. Zurita, A. Carvallo, P. Ramírez, E. Bravo, N. Baloian, Automatic content analysis of student moral discourse in a collaborative learning activity, in: D. Hernández-Leo, R. Hishiyama, G. Zurita, B. Weyers, A. Nolte, H. Ogata (Eds.), Collaboration Technologies and Social Computing, Springer International Publishing, Cham, 2021, pp. 3–19. doi: 10.1007/978-3-030-85071-5_1.
[19] L. Albo, M. Beardsley, I. Amarasinghe, D. Hernandez-Leo, Individual versus computersupported collaborative self-explanations: How do their writing analytics differ?, Institute of Electrical and Electronics Engineers Inc., 2020, pp. 132–134. doi: 10.1109/ICALT49669.2020.00046.
[20] C. P. Rose, Discourse analytics, Handbook of Learning Analytics (2017) 105–114. doi: 10.18608/HLA17.009.
[21] D. S. McNamara, L. K. Allen, S. A. Crossley, M. Dascalu, C. A. Perret, Natural language processing and learning

analytics, Handbook of Learning Analytics (2017) 93–104. doi: 10.18608/HLA17.008.

[22] I. Amarasinghe, D. Hernández-Leo, E. Theophilou, J. Roberto Sánchez Reina, R. A. L. Quintero, Learning gains in pyramid computer-supported collaboration scripts: Factors and implications for design, in: D. Hernández-Leo, R. Hishiyama, G. Zurita, B. Weyers, A. Nolte, H. Ogata (Eds.), Collaboration Technologies and Social Computing, Springer International Publishing, Cham, 2021, pp. 35–50. doi: 10.1007/978-3-030-85071-5_3.

[23] T. Atapattu, K. Falkner, M. Thilakaratne, L. Sivaneasharajah, R. Jayashanka, An identification of learners' confusion through language and discourse analysis, 2019. URL: https://arxiv.org/abs/1903.03286v1.arXiv: 1903.03286.

[24] J. J. Jiang, D. W. Conrath, Semantic similarity based on corpus statistics and lexical taxonomy, CoRR cmp-lg/9709008 (1997). URL: http://arxiv.org/abs/cmp-lg/9709008.

[25] W. Medhat, A. Hassan, H. Korashy, Sentiment analysis algorithms and applications: A survey, Ain Shams Engineering Journal 5 (2014) 1093–1113. doi: 10.1016/J.ASEJ.2014.04.011.

[26] D. Hernández-Leo, E. D. Villasclaras-Fernández, J. I. Asensio-Pérez, Y. Dimitriadis, I. M. Jorrín-Abellán, I. Ruiz-Requies, B. Rubia-Avi, Collage: A collaborative learning design editor based on patterns, Educational Technology & Society 9 (2006) 58.

[27] K. Manathunga, D. Hernández-Leo, Authoring and enactment of mobile pyramid-based collaborative learning activities, British Journal of Educational Technology 49 (2018) 262–275. doi: 10.1111/BJET.12588.

[28] K. Manathunga, D. Hernández-Leo, Pyramidapp: Scalable method enabling collaboration in the classroom, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 9891 LNCS (2016) 422–427. doi: 10.1007/978-3-319-45153-4_37.

[29] P. Dillenbourg, F. Hong, The mechanics of cscl macro scripts, International Journal of ComputerSupported Collaborative Learning 2007 3:1 3 (2008) 5–23. doi: 10.1007/S11412-007-9033-1.

[30] P. Dillenbourg, Over-scripting cscl: The risks of blending collaborative learning with instructional design, Three worlds of CSCL. Can we support CSCL (2002) 61–91. URL: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.457.9255&rep=rep1&type=pdf.

[31] T. Anderson, J. Shattuck, Design-based research: A decade of progress in education research?, Educational Researcher 41 (2012) 16–25. doi: 10.3102/0013189X11428813.

[32] T. Amiel, T. C. Reeves, Design-based research and educational technology: Rethinking technology and the research agenda, Journal of educational technology & society 11 (2008) 29–40.

[33] J. Pujara, H. Miao, L. Getoor, W. Cohen, Knowledge graph identification, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 8218 LNCS (2013) 542–557. doi: 10.1007/978-3-642-41335-3_34.

[34] J. Ramos, et al., Using tf-idf to determine word relevance in document queries, in: Proceedings of the first instructional conference on machine learning, volume 242, Citeseer, 2003, pp. 29–48.

[35] R. Brunken, J. L. Plass, D. Leutner, Direct measurement of cognitive load in multimedia learning, Educational Psychologist 38 (2003) 53–61. doi: 10.1207/S15326985EP3801_7.

[36] R. S. Nickerson, Understanding understanding, American Journal of Education 93 (1985) 201–239. doi: 10.1086/443791.

Adopting creative pedagogy for STEAM education in technology enhanced environments

Yagmur Cisem Yilmaz

Tallinn University, Narva Road 29, Tallinn, 10121, Estonia

Abstract

Employing an arts-integrated Science, Technology, Engineering, and Mathematics (STEAM) approach to education benefits the students by triggering creativity and innovative thinking. By teaching through STEAM, the teachers can better make connections between subjects and students understand the interconnectedness of those fields. Introducing creativity through the arts when teaching complex topics aids students in becoming creators of their knowledge, as they can explore ways to make connections between disciplines and obtain specific information by taking initiatives, individually or collaboratively. The idea of bringing together the creative approaches of learning, and taking ownership of the learning process initially requires a creative pedagogical approach. This approach of teaching to be creative is claimed to be one of the most successful ways of learning [1]. However, integrating creative pedagogy into technology became a necessity as technological advancements have been transforming the teaching and learning experiences. Intersecting the creative pedagogy (the arts in STEAM) and technology-enhanced learning establishes new outlets of interdisciplinary teaching and learning. The recent global COVID-19 pandemic has caused an abrupt transition to distance education that required the integration of technology and digital platforms into everyday teaching because teaching and learning have started to happen in online environments. Such transitions have inspired educators to notice that they could adopt digital interventions in their classrooms. This educational design research aims to further understand and develop a set of digital design principles that aims to bring together interdisciplinary topics of STEAM by utilizing arts. To illustrate and demonstrate different levels of uses of these design principles, a multi-layered digital structure will be built. The design process is planned to be co-created by high school teachers with the consideration of how we could help and support students with diverse backgrounds and interests, and teachers with different technical and artistic competencies. The expected result is theorization and the utilization of the design principles in integrating interdisciplinary subjects through arts.

Keywords [1]

Creative pedagogies, technology-enhanced learning, STEAM education, distance education, and interdisciplinary.

1. Introduction

STEAM (Science, Technology, Engineering, Arts, and Mathematics) is an acceleratingly popular educational approach that had been first idealized in the Americans for the Arts-National Policy Roundtable in 2007 to incentivize students to obtain skills linked to STEM (Science, Technology, Engineering, and Mathematics) fields [2]. Arts guide a larger number of students into understanding interdisciplinary connections through abstract ideas, and use those concepts to solve real-life problems [3]. Including arts in

Proceedings of the Doctoral Consortium of Sixteenth European Conference on Technology Enhanced Learning, September 20–21, 2021, Bolzano, Italy (online).
EMAIL: ycisem@tlu.ee
ORCID: 0000-0001-8580-4881

the STEM curriculums help the students to build necessary skills for their careers in the 21st century [4, 5]. As Colucci-Gray et al. [6] states: combining scientific practices with design, innovation, and artistic expressions is "integral to the process of thinking." (p.2). Platz [7] stresses that student who practice In an arts-domain perform better in their STEM courses because they feel interested and motivated about the new information. However, literature shows that STEAM practices vary vastly, with no coherent description or methods to align with the learning goals. In their extensive literature review, Perignat and Katz-Buonincontro [2] have found that STEAM has been employed as a "pedagogical tool" to integrate arts into STEM fields (p. 38). Learning through arts is stressed to be easing the long-term retention for students [8] motivating them to be creative and innovative, and supporting their cognitive involvement by guiding them to construct their knowledge. What Kahu [9] identified to be major agents of student engagement are also linked to some expected outcomes of learning through arts: behavior, cognitive, affection. Behavior is about positivity towards the subject and initiation of learning such as researching, asking questions during lessons, etc. The cognitive aspect is about self-regulation where students plan and execute their long-term learning goals. The affection aspect is about students' emotions and interest in the task. This research follows a similar approach towards student engagement, however, it differentiates by including a fourth agent about the instruction and the environment, that corresponds to Fredricks et al. 's [10] conceptualization. Although we can use these elements to identify student engagement and use this awareness to improve and shape the intervention accordingly, it will remain to be a construct that only aims to regulate learning in a way to engage students.

Engaging students does not necessarily require the learning to occur, letting aside achieving successful learning. However, when an immediate change is due, like in the COVID-19 pandemic outbreak, retaining student involvement and engagement to promote learning becomes a challenge. Once schools all around the globe have transformed to distance education where all the teaching activities take place online and where every participant joins from another location, disputes have arisen while transforming the teaching material and the teaching approaches. To overcome these issues, school administrations and the teachers have tried multiple methods of online-friendly transformations that include digitizing the content (i.e. scanning worksheets, taking photos of the visual teaching materials, etc.), scheduling virtual classes on video teleconferencing software (to replace real-classes, by utilizing Zoom, Google Meets, Skype, etc.) [11], and facilitation of quizzes through online platforms while asking the students to keep their camera on to ensure they do not cheat. Although they seem to be feasible solutions, none of them are considered efficient in the long-term adaptation [10, 11]. Regardless of their sufficiency, distance education is turning into a preferable method of instruction.

With the rise in the use of distance learning, students experience motivational problems [12] due to learning from a distance as it does not involve as much interaction and requires much self-regulation and independence. Motivational correction is considered to be easier in classroom settings as the teachers have the opportunity to observe and intervene with the students directly [12], but the integrity of student motivation and engagement becomes a challenge in partially digital and innovative teaching content. By this, the partially digital teaching contents address the digitized versions of blueprint teaching materials and classroom approaches. In the pre-COVID-19 world, education technologies were developing swiftly, and much research had been undertaken about implementing technological solutions into educational problems such as aiding student engagement, measuring and tracking student participation, and personalizing the learning outcomes. Technology-enhanced environments and learning strategies have supported and made room for such innovation to happen, but lacked practicality [13] due to limited dissemination. Technology-enhanced environments allow teachers and students to integrate the course format fully into online distance learning or in-classroom according to their needs, and by doing so, achieving an immersive learning experience that promotes engagement and motivation in students. Technology-enhanced environments are settings that are used by the instructors, facilitators, teachers, and learners for helping students to obtain knowledge and skills through the means of technological resources, and tools [13, 14]. The term technology-enhanced environments is used to address both online distance learning platforms and the actual classrooms that are equipped with technology.

The COVID-19-caused rapid transition to online distance learning has illustrated where and how technology-enhanced learning was needed and could be adopted. However, such awareness does not tell much about the students' side of the learning experience, that is, the student's motivation, engagement, curiosity, and learning. As it has been stated, students struggle in remaining motivated during distance learning [15] which can potentially influence their engagement and learning. However, introducing an arts-related activity in lesson plans can help improve students' motivation and engagement. Especially considering the difficulty in keeping the students' focus and engagement in STEM classes, it becomes vital to integrate an artistic mediatory in the teaching approach because artistic expressions can support students in becoming interested in the knowledge they acquire [7, 8]. Dewey [16] has suggested that arts education is one of the core parts of the curriculum because arts help "develop creativity, self-expression, and an appreciation of the expression of others." [17, p.136]. Therefore, it is necessary to apply STEAM approaches with an artistic focus on technology-enhanced environments. However, such applications do not function well in a short-term intervention [15] as it causes a disrupted cognitive fulfillment for not allowing enough time to build creativity and solution-orientation. Instead, the students will focus on logic-based explanations that explicitly aim to describe the current state of a problem or phenomena [8]. Such an approach does not support trial-error during learning which negatively impacts the self-efficacy of students. Therefore, the teachers need to be equipped with tools and competencies that will enable them to design and integrate artistic activities on technology-enhanced environments.

The challenge resides in transforming the pedagogical approach, as solely shifting the teaching materials is not sufficient and sustainable action towards improving student engagement. Therefore, we aim to adopt a pedagogical approach that can stimulate student interaction, creativity, willingness, and engagement altogether to provide successful learning. Bringing together all these desirable attributes seems feasible with a creative pedagogical direction. Although STEAM suggests interdisciplinary learning, it seems that arts are always used as a method to teach STEM subjects and not as the target subject to be taught, making it hard to place the arts among the others as an equal field [18]. Moreover, the diverse and clashing practices of STEAM can hinder inclusion of creativity, however, the lack of research in the approaches of creative pedagogies can be a challenging step in determining the benefit of teaching creativity [2, 19]. To overcome this challenge and address the "A" in STEAM education, this research will refer to creative pedagogy. The term refers to a sum of teaching through artistic methods in this research. Lin [20] addresses creative pedagogy as an intersection of teaching for creativity, learning creatively, and teaching creatively which also integrates both the teachers' and the students' role of learning creatively. Although having the role of learner can initiate an exhaustive philosophical discussion on learning to learn and the role of the teacher and the student in the classroom, Aleinikov [1] describes creative pedagogy in a more practical sense; as a way to initiate life success by introducing the learners to create their knowledge, to think out-of-the-box (creativity skills), and to be innovative.

Creative pedagogies are an inherent approach to teaching creatively to guide students in taking ownership and responsibility of their learning in all study fields. The teacher fosters the role of the tutor who structures the courses and supports students to build self-efficacy to overcome real-life problems, and scientific inquiries [8]. By instrumentalizing arts to teach STEM creatively, the teachers can help their students to understand how diverse-looking disciplines interconnect. The creativity aspect has been influenced by the introduction of educational technologies into everyday learning. The combination of both has accelerated the process of involving technologies in learning to keep the students engaged and make their learning success. With the current global pandemic, in-classroom education has been transitioned to distance education all around the world. This shift caused many teachers to struggle with the new structure of teaching and the needed technological competencies, students faced hardship on maintaining interest and remaining engaged with course material. Therefore, we need to instrumentalize more of the digital tools or approaches that are inclusive of distance education. To fulfill such potential, and establish new aspects to the current pedagogical approaches, it becomes a necessity to challenge the traditional sense of creativity and education by rethinking and redesigning STEAM education scenarios that could be applied to distance or contact education. In the intersection of creative pedagogies and TEL, incentives, and interventions relating to technological creative teaching approaches stand. However, the current tools and interventions need some development to bring these aspects together.

This research accepts the constructivist approach and integrates pragmatic reasoning to it to develop a set of design principles to be employed for teaching interdisciplinary concepts through arts digitally, and to design an intervention that demonstrates methods to utilize those design principles.

2. Methodology

The aim of this research is to propose a framework of design principles to integrate arts and one or multiple STEM subjects by demonstrating a set of digital activities on a to-be-designed digital construct. This aim is portrayed by the initial question of this research: *what attributes are effective and sustainable in a digital design that aims to educate upper secondary school students on STEM subjects through arts?* To address that big question and to achieve the research purpose, the following overarching questions will be investigated:

1. How do teachers and students combine information that originates in different knowledge domains of STEAM?
2. What are the current awareness, practices, and challenges of teaching interdisciplinary STEAM subjects digitally in upper secondary schools in Estonia?
3. What are the characteristics of a well-functioning and engaging digital artistic intervention for the purpose of integrating multidisciplinary learning strategies?
4. What types of characteristics do the digital artistic interventions should constitute to stimulate students' interest and engagement on a complex interdisciplinary STEM topic?

To accommodate the layered structure of the research questions, and to generate key characteristics of interdisciplinary design principles of STEAM, this research will adopt a mixed-method design-based approach. There are four major phases of the design research to compose the final outcome of this project, namely: (1) analysis, (2) development, (3) evaluation and revision, and (4) dissemination. Each phase constitutes iterative processes to enable rebuilding, and amending the prototype and the included design principles. The research design is an altered combination of McKenney and Reeves' [21], and Plomp's [22] educational design research models. The interaction between phases and the cyclical research model of this research is illustrated in Figure 1.

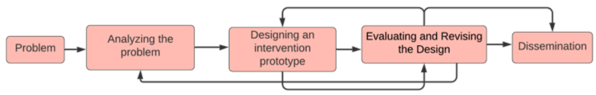

Figure 1: The design-based research model adapted for this research

The preliminary analysis phase consists of (1) a detailed literature review to identify the current digital practices of STEAM education, and those activities' advantages and drawbacks, (2) an analysis of the current awareness, practice, competence, and approach of upper secondary school teachers (of STEAM fields) towards teaching STEM subjects through arts (creative pedagogy) and on digital platforms. Only one data collection is intended for this stage to gather information on the 2nd factor of this phase. The data will be collected by the means of survey questionnaires with close-ended questions, and semi-structured interviews with teachers. The teachers will be acknowledged about the further proceedings of this research and asked to join for the other phases. This direct invitation would be one of the methods to employ participants. After obtaining descriptive results from the first phase, the development stage will commence in accordance with the findings.

The development and the evaluation phases are strongly interconnected and are planned to have at least three cycles to mature the intervention and to achieve the intended outcomes. The teachers will be employed through the network of other PhD candidates and colleagues working on technology-enhanced learning and educational technologies at Tallinn University. The teachers will be partners in this research as they will be responsible for participating in co-creation workshops to brainstorm and develop the intervention idea. Upon developing a prototype, the teachers will try it in their classroom, observe their students for engagement and behavioral changes. They will include their feedback and in-class activity assessments to identify whether the tool had been used with intended purposes and whether it helped to teach interconnected STEAM subjects. According to the evaluation reports from the teachers, and data analysis, the intervention will be revised accordingly. During this process, it becomes vital to understand the students' perspective of interacting with a digital tool aiming to teach STEM subjects with the help of the arts. To gain insight, the students will be asked to fill in a pre-questionnaire about their expectations, and their awareness of integrating arts with other STEAM subjects. Then, they will be asked to keep a record of their experience in an activity log; so it will enable the teachers and the researcher to classify whether there were any unintended uses. The data obtained from the teachers and the students will be analyzed collectively for identifying mismatches between the observation of the teacher and the self-reports of the students.

By utilizing the intervention and gathering insightful data from both the teachers and the students, this research can become aware of what design principles are commonly used to integrate interdisciplinary subjects. Such design principles are necessary to determine a framework for creating a digital intervention for teaching STEAM interdisciplinary by purposefully utilizing the arts.

The intended intervention is a digital structure that resembles a bookcase that has developmental archival storage. The main objective is to combine the same set of design principles in each level to illustrate the uses among simplistic to complex interdisciplinary design ideas. The first level will consist of ideas where the teachers could select certain expected outcomes or topics to integrate, it functions in a way that the teachers will determine their needs and request a ignite to pursue that idea. The second layer will suggest the teachers incorporate some additional tasks onto their selection, and by doing so obtain extra learning objectives as a result. These two layers will be co-developed by the researcher and the teachers. These two layers will list down certain materials that are accessible through a hyperlink. This way, the teachers could assign students with certain tasks, and send them the link to access the materials without needing to hand in task maps, materials, etc.

The third layer will introduce arts (fine arts, music, plastic arts, literary arts) as parts of the integration. For instance, students are given Leonardo da Vinci's drawings and paintings in a class that aims to teach certain mathematical phenomenon. The last layer builds upon the third one by allowing users to download activities, and upload their newly created artistic expression projects that aim to teach STEM subjects. New creations are an updated version of the activities on the third level or transformed versions of those tasks. Such a complex construct will predicate on the same design principles which will demonstrate the convenience of adopting creative pedagogy on digital tools. As the base principles remain the same for each layer of the intervention, it is intended to welcome and encourage teachers of different competence levels.

Although the ambitious goal is to integrate all disciplines of STEAM (in different combinations or altogether) in the digital structure, such a plan becomes unrealistic and unapproachable due to time and budget constraints. Therefore, this project will determine one of the non-arts STEAM fields and focus on that field during this research. However, that selection will be made upon meeting with teachers and gathering more insight through data. The intervention will aim to:

- Demonstrate the design principles of how to bring together different STEAM disciplines by purposefully utilizing arts.
- Showcase how the design principles could be successfully implemented in different levels of digital structures and designs.
- Support student engagement and interest with creative interdisciplinary

tasks on the developed digital structure.

- Overcome the technology-competence barrier of the teachers, and encourage them to take ownership and be creative in their profession.
- Help the teachers to explore ways for guiding their students through complex interdisciplinary relationships.

2.1. Ethical consideration, limitations, and expected responsibility distribution

Language barrier resides to be the primary limitation of this research. I do not speak Estonian and need to work with students who can communicate in English, or ask the teachers to translate the conversations/data. Alternatively, working with a MA Educational Sciences student during data collection can help me overcome this challenge.

As I am a new-starter of coding, it may be challenging to produce the intervention by myself or with the sole support of the teachers, and I may need to work side by side with a programmer. However, as the intervention is not going to be a mobile application that requires more complexity, this limitation will be overcome by using online platforms to generate content that is to be utilized as a demonstrative and functioning design.

Teachers will be in direct contact with the students, and as some students might feel obliged to comply with the teacher's requests or instructions, this may arise power-related problems. Another power issue could reside in the relationship between the teacher and the researcher. We can overcome the latter by assigning the teachers to be action researchers alongside being co-creators. The teachers will be responsible for tracking their students' progress, interest, and success. Alongside the interventions' influence on the students, the teachers will be responsible to note any positive (the intervention works in favor of students' learning, and teachers' ability to use it), and negative (misuse of the intervention- if possible, lacking function and purpose) influence of the intervention. The teachers will be asked to gather these observations, and notes together to share their experience with the researcher. We will ask students to provide us with individual and group feedback to share their opinion of the intervention, and if they think this new tool works for them with the reasoning behind them. Then, we will ask students to tell us how we could improve this intervention that they would prefer using it.

The researcher is responsible for (1) categorizing and analyzing all data including the student feedback, (2) co-creating the intervention with the teacher, (3) noticing the patterns in the design that may be challenging, and (4) identifying design principles in the process of development. The teachers will be responsible for (1) co-creating the design, (2) working as action researchers who are willing to improve their professional skills, (3) collecting data from the students, and (4) taking observation notes and writing feedback during their classes.

2.2. Expected outcome and significance

This research starts with a goal to identify the characteristics of the effective implementation of arts subjects into STEM subjects on digital environments and platforms by producing a curated medium through analyzing the existing approaches and practices alongside this research. It is expected to establish a set of digital design principles for integrating arts into teaching, and a reliable tool that helps teachers to teach STEM subjects through arts while creating a basis to encourage further research adopting the design principles.

The intervention can be employed by higher education institutions in the future, especially for teaching engineering students to foster creativity, innovative thinking, and communication in their professional life. The intermediary digital structure is planned to be a demonstration of how such design principles could be utilized and employed. By doing so, I aim to provide an explanatory and prescriptive theory that can guide other research in a similar field, especially investigating the interconnections of STEAM subjects, and the methods of teaching and learning these subjects in alignment with their interconnectivity. The tool and the design principles behind it will be used to elaborate and clarify some of the fuzziness in the practice and theory about TEL-empowered STEAM education.

The arts in STEAM are used solely for the purpose to be a way to teaching STEM subjects, making the arts-related studies considered insignificant for both the learner and the teacher. However, it has been evident that art studies alongside or through STEM subjects provide ground for growth by integrating 21st-century skills and inclusivity. Therefore, this research will focus on developing a framework of design principles for TEL-empowered STEAM subjects, minding the value the arts acquire in the teaching and learning practices.

Each phase of this research will contribute to the development of these design principles. First, the analysis stage will help to elaborate on what digital practices of STEAM have functioned effectively, and in what ways those aspects can be integrated into a design together. Then, the key principles of multidisciplinary integrations are understood better and are merged in the initial development. Although certain practices and activities might have worked in the future, it does not ensure a functioning design when they are put together. The development and prototyping phase will help explore which combinations of design principles work well together, in the sense of engaging students by integrating two or more disciplines. The practical aspect of this research will demonstrate the methods of incorporating and utilizing the core design principles for multidisciplinary education in classrooms and distance education.

2.3. Timeline

This research will be undertaken in the nominal period of a doctoral degree in Estonia which is 4 years. To cover all aspects that are considered necessary in this research plan, each year of the doctoral study will have an overall theme of research. Although Figure 2 illustrates the timeline as a linear and progressive chart, the development phase consists of multiple cyclical studies that aims to clarify and advance the set of design principles to utilize in integrating numerous topics into an interdisciplinary learning context and outcome.

The first year focuses on analysis of the current knowledge and practices of STEAM in Estonian upper secondary schools (excluding vocational schools), and the exploration of the common attributes of digital tools of an effective and sustainable integration of arts into STEAM education. The second and third years will focus on development cycles that involve designing an intervention based on the design principles, testing it with teachers and students, and revising the design according to the feedback received from the users and the evaluation of whether the intervention enables other interdisciplinary work.

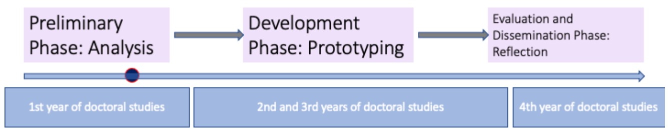

Figure 2: The brief timeline of this research

3. Acknowledgements

First and foremost, I'd like to take this opportunity to thank my supervisors Dr. Terje Väljataga and Prof. Dr. Tobias Ley for helping me in finding my way around towards tangible directions. Additionally, I appreciate all my colleagues at Tallinn University for their support and discussions that help me elevate this research.

4. References

[1] Aleinikov, A. G.: Creative Pedagogy. Encyclopedia of Creativity, Invention, Innovation and Entrpreneurship, 326–339 (2013). doi:10.1007/978-1-4614-3858-8_13.

[2] Perignat, E., Katz-Buonincontro, J.: STEAM in practice and research: An integrative literature review. Thinking Skills and Creativity (31), 31–43 (2019). https://doi.org/10.1016/j.tsc.2018.10.002.

[3] Kang, M., Park, Y., Kim, J., Kim, Y.: Learning outcomes of the teacher training program for STEAM education. International Conference for Media in Education, Beijing (2012).

[4] Hau, N. H., Cuong, T. V., Tinh, T. T.: Students and teachers 'perspective of the importance of arts in STEAM education in Vietnam. Journal of Critical Reviews, 7(11), 666-671 (2020).

[5] Shatunova, O., Anisimova, T., Sabirova, F., Kalimullina, O.: STEAM as an Innovative Educational Technology. Journal of Social Studies Education Research, 10(2), 131-144 (2019). https://www.learntechlib.org/p/216582/ Last accessed 20 October 2021.

[6] Colucci-Gray, L., Burnard, P., Gray, D., Cooke, C.: A Critical Review of STEAM (Science, Technology, Engineering, Arts, and Mathematics). In: Oxford research encyclopedia of education, pp.1-26. Oxford University Press, Oxford (2019).

[7] Platz, J.: How do you turn STEM into STEAM? Add the arts. Columbus: Ohio Alliance for Arts Education, 1-5 (2007).

[8] Conradty, C., Bogner, F. X.: From STEM to STEAM: Cracking the code? How creativity & motivation interacts with inquiry-based learning. Creativity Research Journal, 31(3), 284-295 (2019).

[9] Kahu, E. R.: Framing student engagement in higher education. Studies in Higher Education, 38(5), 758–773 (2013). https://doi.org/10.1080/03075079.2011.598505.

[10] Fredricks, J. A., Blumenfeld, P. C., Paris, A. H.: School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74(1), 59– 109 (2004). https://doi.org/10.3102/00346543074001059.

[11] Sastre-Merino, S., Nunez, J. L. M., Pablo-Lerchundi, I., Nufiez-del-Rio, C.: Training STEAM Educators in the COVID-19 emergency situation: Redesigning teaching. In: 2020 Sixth International Conference on e-Learning (econf), pp. 72-75. IEEE (2020). https://doi.org/10.1109/econf51404.2020.9385461.

[12] Visser, L., Plomp, T., Amirault, R. J., Kuiper, W.: Motivating students at a distance: The case of an international audience. In: Educational Technology Research and Development 50 (2), 94–110 (2002). https://doi.org/10.1007/bf02504998.

[13] Wang, F., Hannafin, M. J.: Design-based research and technology- enhanced learning environments. In Educational Technology Research and Development 53(4), 5–23 (2005). https://doi.org/10.1007/bf02504682.

[14] Aleven, V., Stahl, E., Schworm, S., Fischer, F., Wallace, R.: Help seeking and help design in interactive learning environments. Review of Educational Research, 73(3), 277–320 (2003).

[15] Stokes, T. F., Osnes, P. G.: The developing applied technology of generalization and maintenance. In: R. H. Horner, R. H., Dunlap, G., Koegel, R. L. (eds.) Generalization and maintenance: Life-style changes in applied settings, pp. 5–19. Paul H. Brookes Publishing, The USA (1988).

[16] Dewey, J.: Art as experience. Penguin, New York (1934).

[17] Heilig, J. V., Cole, H., Aguilar, A.: From Dewey to No Child Left Behind: The Evolution and Devolution of Public Arts Education. Arts Education Policy Review 111(4), 136–145 (2010). https://doi.org/10.1080/10632913.2010.490776.

[18] Mejias, S., Thompson, N., Sedas, R. M., Rosin, M., Soep, E., Peppler, K., Roche, J., Wong, J., Jurley, M., Bell, P., Bevan, B.: The trouble with STEAM and why we use it anyway. Science Education, 105(2), 209-231 (2021).

[19] Smith, J. K., Smith, L. F.: Educational creativity. In: Kaufman, J. C., Sternberg, R. J. (eds.). The Cambridge handbook of creativity, pp. 250–264. Cambridge University Press: New York (2010).

[20] Lin, Y.: A third space for dialogues on creative pedagogy: Where hybridity becomes possible. Thinking Skills and Creativity 13, 43-56 (2014). https://doi.org/10.1016/j.tsc.2014.03.001.

[21] McKenney, S., Reeves, T. C.: Conducting educational design research. Routledge, Oxon (2012).

[22] Plomp, T.: Educational design research: An introduction. In: Plomp, T., Nieveen, N. (Eds) Educational Design Research, pp.11-50. Netherlands Institute for Curriculum Development, Enschede (2013).