Chapter

Facilitating Collaborative Learning with Virtual Reality Simulations, Gaming and Pair Programming

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Abstract. The chapter presents socio-interactional functions that support collaborative learning through three case examples. The examples stem from our long line of empirical research in which we have explored the possibilities of using various types of emerging digital technologies for enhancing collaborative learning and interaction. We present case examples from technology-enhanced simulation-based learning environments, Vive/Minecraft applying XR/VR and pair programming in a creative media project design with Scratch, which are all regarded as powerful experiential learning contexts that can provide engaging opportunities for collaborative learning.

Keywords: Collaborative learning, Teacher-student interaction Simulation-based learning environments, Gaming, Pair programming, Virtual reality, XR/VR, Vive/Minecraft, Scratch

1.1 Introduction

Technological innovations are broadening learning and interaction opportunities by augmenting, enriching, and adaptively guiding learning and interaction. New research is especially keen on the potential of virtual (VR) and mixed reality (XR) (Blascovish and Bailenson 2006; Johnson and Levine 2008; Lau and Lee 2015; Radianti et al. 2019; Stavroulia and Lanitis 2019), game-based learning platforms (Baek et al. 2020; Qian and Clark 2016) and creative programming (Brennan and Resnick 2012; Georgiev et al. 2017; Iwata, Pitkänen et al. 2020) to offer immersive and engaging learning contexts. For several decades, interest has particularly been in developing technologies for social learning interaction in a framework of collaborative learning (Jeong and Hmelo-Silver 2016). In general, collaborative learning is a powerful context for enhancing individuals' learning and is also effective for developing group working skills (Roschelle 1992). Collaborative learning is built through interaction processes of sharing, questioning and justifying ideas and understanding social interaction (Chi, 2009; Dillenbourg 1999). Digital learning environments afford new types of opportunities for learners to engage and participate in collaborative learning activities (Laru et al. 2015; Ludvigsen and Steier 2019). In particular, immersive environments add the aspect of human-technology interaction to the learning situation (Lau and Lee

2015; Radianti et al. 2019). Technology is changing both ways of learning and ways of teaching or facilitating learning and interaction. To further guide the implementation of technology in education in pedagogically meaningful ways, we need more evidence of how technology is affecting collaborative learning, teaching, and interaction processes (Järvelä et al. 2020; Marin et al. 2016; Näykki et al. 2019; Radianti et al. 2019).

In general, the role of a teacher is changing, and a collaborative learning approach means a shift away from a teacher-centred approach to an approach that extends the teacher's role from information transmission to a designer of the learning experience (Kaendler et al. 2015; Laal and Laal 2012). The aim is to empower students to take an active role in planning and conducting their learning activities in groups, and the teachers' role is, thus, to foster beneficial student interaction or design optimal conditions for collaboration, while giving direct support when needed to the students with cognitive, metacognitive, emotional and motivational activities (Kaendler et al. 2015). The current questions are: How are new and emerging digital technology providing engaging and creative collaborative learning environments, and what kinds of interactive functions do they support to afford to establish meaningful interactions with and among users?

This book chapter seeks answers to these questions by elaborating socio-interactional functions that support collaborative learning through three case examples. The examples stem from our empirical research in which we have explored the possibilities of using various types of emerging digital technologies for enhancing collaborative learning and interaction. We present case examples from technology-enhanced simulation-based learning environments, Vive/Minecraft applying XR/VR and pair programming in a creative media project design with Scratch, which are all regarded as powerful experiential learning contexts that can provide engaging opportunities for collaborative learning. These three examples were chosen because of their likely impact on learning and instruction in current and future educational designs (Chang et al. 2018; Huang et al. 2019).

1.2 Group engagement as a central part of collaborative learning

Collaborative learning is a specific type of learning and interaction process in which learners in a group share their overall learning process by negotiating their goals for learning and coordinating their mutual learning processes together (Roschelle and Teasley 1995). As the process of collaborative learning consists of discussions, negotiations, and reflections on the task at hand, it has the potential to lead to deeper information processing than individuals would achieve alone (Baker 2015; Dillenbourg 1999). The premise for successful collaborative learning is that group members are actively engaged in building, monitoring, and maintaining their shared learning processes on cognitive and socioemotional levels (Barron 2003; Isohätälä et al. 2020; Näykki et al. 2017). This suggests that interpreting and understanding how your actions and emotions affect others is essential to obtaining successful collaborative learning (Linnenbrink-Garcia et al. 2011; Miyake and Kirschner 2014).

We ground our studies in the increasing empirical understanding of the multifaceted interaction processes involved in collaborative learning, integrating cognitive and socioemotional components as the core of collaboration (Järvelä et al. 2013; Järvelä et al. 2010; Näykki et al. 2014; Ucan and Webb 2015; Volet et al. 2009; Vuopala et al. 2019). Thus, collaborative learning requires group members to be aware of and to coordinate their cognitive, metacognitive, motivational, and emotional resources and efforts (Hadwin et al. 2018) by sharing their thinking and understanding, as well as showing verbally and behaviourally their commitment and engagement to the task and to the group (Järvelä et al. 2016). In addition to group activities, teacher-student interaction is essential in guiding students' engagement in learning. This means that how the teacher provides feedback and encouragement to students individually and as a group can have an effect on students' learning engagement (Kaendler et al., 2015; Van de Pol et al. 2019).

In general, researchers agree that engagement is a central part of collaborative learning and have defined it as a meta-construct encompassing at least three dimensions: behavioural, emotional, and cognitive (Fredricks et al. 2004; Sinha et al. 2015). Behavioural engagement refers to positive conduct and active involvement in learning and participation in task activities. Emotional engagement is characterized through affective reactions of students during learning processes, how learners feel and manifest their feelings in the learning situation, and how socio-emotionally engaged are group members to the group's task. Cognitive engagement is highlighted as cognitive investments and the use of deep learning strategies when learning collaboratively as a group. The theoretical ideas behind cognitive investments in collaborative learning follow Roschelle's (1992) notion of cognitive convergence: group members construct shared knowledge by monitoring the degree to which they understand each other's thinking, extend other people's ideas, acknowledge divergent interpretations, and resolve inconsistencies between the ideas that have been proposed. The premise underlying such learning relates to a process of explicating one's own ideas and engaging cognitively in the ideas of others (Webb et al. 2014).

However, students' engagement in collaborative learning situations requires skills that are different from and often more challenging than the skills required for individual learning (Häkkinen et al. 2017). To develop collaborative learning skills and afford learners possibilities to function as cognitively and socio-emotionally engaged group members, learners need their own experiences of collaboration-based instructional approaches with authentic and complex problems (Hmelo-Silver and Barrows 2008). Technology is a natural part of this type of authentic learning.

1.3 Emerging technologies as support for engagement in collaborative learning

We present and explore three case studies involving simulations using a virtual reality environment for learning, games for learning, and programming where emergent and contemporary technologies are used to support collaborative learning in open problem spaces, especially focusing on collaborative learning interactions and interaction processes between the student and the teacher. These emergent digital tools, with their respective socio-technical designs, were selected because they each represent different opportunities for learning. VR and XR technologies and simulations provide an immersive technology-enhanced context for experiential learning and a reflective discussion between the student and the teacher, while games and programming are contexts for creative learning. These technologies have often been present in informal contexts as associated with the social lives of the users, which may thus explain one of the reasons why they are able to access learners' engagement in powerful ways. These technologies hold the potential for learning in formal education as well, as a part of learning activities organized by educational institutions (Pedro et al. 2018; Vesisenaho et al. 2019).

1.4 Forestry VR simulations in vocational education

Lately, there has been great interest in virtual reality simulations because of their potential to provide engaging, experiential, and immersive situations and contexts for learning (Kwon 2019; Pine and Gilmore 1999; Radianti et al. 2019). A recent analysis from 145 empirical studies of higher education contexts showed that simulation-based learning (SBL) is effective in facilitating the learning of complex skills across domains (Chernikova et al. 2020). For example, in SBL, one can use or practice approaches that cannot be reached easily, safely or practiced at all in real life (Lateef 2010). The SBL method is widely used, especially in safety-focused contexts such as aviation, healthcare, and the nuclear industry, where it provides possibilities for a repetitive practice of skills without major risks. Simulation is not a technology as such, even though technology often has a significant role in SBL (Lateef 2010). In simulations, the learner typically has scenario-based problems or real-world problems to solve or skills master, and the teacher has the role of supporting this task in collaboration with the learner. The skills practiced can be either technical or non-technical in nature. New technological applications, such as VR and game-based learning platforms, offer immersive contexts for SBL, providing high realism targeting to afford learning experience as authentic and engaging as possible (Lateef 2010). The type of simulation depends a lot on each learning context and has its benefits in being an environment that can be tailored according to the learning needs (Chernikova et al. 2020). Simulations may evoke strong and powerful emotions with authenticity, and thus, increase learning engagement in behavioural, cognitive and emotional dimensions (Bearman et al. 2013).

In vocational education, simulations are implemented to enable a better connection between the educational setting and the professional skills needed in the field; however, very little yet is known from the student's perspective (Jossberger et al. 2017). Jossberger and colleagues (2017) argue that the presence and guidance of the teacher plays an essential role in the simulation process and, further, they point out that even though simulations demand self-direction and commitment, the learning activities and processes are not sufficiently promoted and supported. In our empirical simulation case studies, we particularly explored learner-teacher interaction and meaningful moments of learning during simulator training (Silvennoinen et al. 2020). A multi-method approach was created to capture learners' experiences during a simulation experiment. We examined the complex nature of the learners' individual experiences and interaction with a teacher, combined with physiological reactions of the body (heart rate measurements) and brain electrophysiological activation by electroencephalogram measurements (EEG) (Silvennoinen et al. 2020; Vesisenaho et al. 2019). The approach enables exploration of learning situations in a natural context from different aspects and the integration of individual experiences, emotions, and physiological and neurophysiological reactions during learning (Figure 1).

The context of this case study is forestry simulations in vocational education, where SBL is integrated into the curriculum of forest harvester operator training. In this vocational education programme, students may also use the simulators alone or with peers in their free time as much as they want. As many of the students lived on campus, they had good opportunities for independent training. The simulator itself offered instructions and feedback relating to each training task, which supported independent and joint training. In this case study, six students and two teachers formed six dyads and participated in an SBL situation consisting of three pedagogical phases: an introduction to a simulation case, actual simulation tasks, and a debriefing discussion with the teacher. During the tasks, each student used HTC T3-D virtual glasses for a more authentic experience and performed four tasks that dealt with typical activities of mechanized harvesting, such as the different actions of a forwarder and a harvester, selecting the right trees to be cut, collecting cut trees, and piling up trees (Figure 2). The tasks were selected by the teacher and became gradually more demanding so that the fourth task—cutting down large trees in the correct directions—was presumably a challenging task for all the students, as none had hardly any previous experience.

Figure 1. Practicing mechanized harvesting (Silvennoinen et al., 2020). Photo taken by Auli Dahlström.

Figure 2. Screenshot of the simulator during a mechanized harvesting task (Silvennoinen et al., 2020).

Before each task, the students received both text-based instructions and video-based examples directly from the simulator. After each task, the students received feedback from the simulator based on their performance in the tasks and discussed the simulator feedback with the teacher. Thereafter, together with the teacher, the students asked, discussed and negotiated, for example, solutions for challenges that emerged during the session. They also had a short debriefing session with the teacher after the training, during which the video recording of the simulator was used to stimulate discussion. In our case study, the students were interviewed individually after the SBL training situation and, with video recordings of the tasks, a stimulated recall method was used to stimulate the student's memory and to discuss the experience in detail. As we were interested in the students' experiences regarding their learning, the students annotated their videos of the tasks with an emphasis on episodes they defined as memorable and considered meaningful for their learning. In addition, the students described emotions they experienced during the training and commented on the successes and challenges of the episodes that they felt were meaningful. Further, they evaluated how it is to drive a simulator compared to a real forwarder or harvester and justified their arguments and preferences. The use of VR glasses was also discussed, and the students carefully explained the benefits and challenges of their use. The students also examined their perceptions of student-teacher interaction and its role in that particular SBL situation, while the teachers shared their views of the interaction on a general level during their individual interviews.

This case study highlighted the strength of SBL to offer students opportunities to practice forestry alone, together with other students, and with the teacher. Through the VR environment, the immersive experience of realistic forestry machines and the forest site were created. VR-enhanced SBL was a new learning experience for the students. In their study programme, similar activities and actions are typically practiced with real forestry machines. In this case study, the simulator instructed them during the tasks and gave automatic feedback to the students after each task performance. It became visible that the students could influence their own training activity, choose suitable tasks, and evaluate their performance with the help of the feedback provided by the simulator.

Thus, both the student and the teacher monitored the learning process, and when necessary, the teachers further guided the students, interacting with the device. Therefore, the simulator was a central part of the student-teacher interaction process, altogether supporting learning. In general, in simulation-based learning contexts, the aim is to empower students to take an active role in reflecting and guiding their own learning processes. Studies have shown that teachers applying SBL methods and VR technology are adopting student-centred approaches (Keskitalo 2011).

1.5 Constructing and exploring Minecraft and Vivecraft with VR glasses

The second case example presents Vive-Minecraft as an XR environment for creative, collaborative, gamified learning processes in K12 education. Currently, there is an increasing interest in implementing games in an educational context (Qian and Clark 2016; Nebel et al. 2016). The affordances of games as a meaningful pedagogical context go beyond their motivational potential; they can facilitate engagement on cognitive, affective, and sociocultural levels (Plass et al. 2015). Connolly et al. (2012) found in their systematic literature review that playing computer games is linked to a range of perceptual, cognitive, behavioural, affective, and motivational impacts and outcomes. However, previous studies have shown that the game environment itself does not guarantee deep learning and meaningful learning experiences (Lye and Koh 2014; Mayer 2015). The challenge is that many educational games follow simple designs that are only narrowly focused on academic content and provide drill and practice methods (Qian and Clark 2016). Careful pedagogical design is needed to implement an educational game as a holistic problem-solving environment. For example, game design elements can provide opportunities for learners' self-expression, discovery, and control. These types of playing activities can create a learning environment that supports students' cognitively effortful and meaningful learning, for example, in terms of programming skills, creativity, and problem solving (Kazimoglu et al. 2012; Qian and Clark 2016), and engagement (Bayliss 2012; Pellas 2014; Zorn et al. 2013).

The use of Minecraft in education taps into two dimensions of game-based learning (Nousiainen et al. 2018; Van Eck 2006): bringing popular existing games into the classroom and providing the learners with an opportunity to create their own game environments. In many cases, the pedagogical potential of creating games can be greater than that of merely playing them, as game-making entails engagement in collaboration and active knowledge construction (Baek et al. 2020; Burke and Kafai 2016; Vos et al. 2011). Previous studies on the use of Minecraft in educational settings have found its pedagogical potential both in terms of student engagement and the acquisition of various skills and knowledge (Baek et al. 2020; Checa-Romero and Gómez 2018; Díaz et al. 2020; Nebel et al. 2016).

In this case study, we designed a learning project related to the topic of energy effectiveness and sustainable development (Kyllönen et al. 2020). The project was implemented as a collaborative effort between teachers and teacher students who jointly created a game-based learning environment for the pupils. The design-based learning process of the 7–10-year-old pupils focused on planning and implementing a sustainable town or village. The pupils’ tasks, supported by teacher students and their own teachers, consisted of information seeking, planning, and finally constructing Minecraft environments and exploring them with Vivecraft and VR glasses (Kyllönen et al. 2020). The pupils designed their own villages and began to collaborate (in a self-directed manner), and some villages were linked by railway or using joint energy sources. The case study showed that the collaborative and open-ended nature of Minecraft provides opportunities for student engagement, creative problem solving and learning different skills and knowledge (Baek et al. 2020; Nebel et al. 2016); however, it also challenges teachers to rethink their role in guiding and supporting the pupils’ learning process. This entails, for example, actively supporting the learners' agency and self-regulation, and identifying and building on so-called teachable moments (Nousiainen et al. 2018; Watson et al. 2011) that emerge from the activities. To conclude, this case provided an example of a constructivist gaming experience in which players can play, modify the game, or even create their own games for learning (Kafai and Burke 2015).

1.6 Pair programming as collaborative creative coding

A third case example presents pair programming with Scratch (Fagerlund 2018; Fagerlund et al. 2020). Collaboration and programming have come as close to one another as ever, especially in primary and secondary education via pedagogical initiatives such as the creative computing movement (Brennan and Resnick 2012) and digital fabrication and the maker culture (Iwata et al. 2020). On this front, we have come to see the rise of increasingly popular graphical programming tools such as Scratch, which was originally developed in 2009, to be more meaningful and social than other existing programming environments. Scratch has evolved to facilitate the design of various kinds of media projects, such as interactive digital games, stories, and animations, by encouraging learners' creative design, self-expression, and personal interest areas. Beyond this, it is also a social platform where young programmers can code together, share their projects, and examine, use, and build on each other's shared projects (Resnick et al. 2003). In schools, Scratch is encouraged for use in social constructivist or constructionist settings via problem-project based approaches to design media projects that are thematically connected to different curricular areas (Garneli et al. 2015; Robles et al. 2018). A key collaborative element in Scratch among other environments comes in the form of *pair programming*, where two or more students can work together at the same computer towards a shared goal (one “driving”, that is, using the computer, and the other one “navigating”, that is, assisting in reviewing the design process). Pair programming has several known educational advantages, including enhancing conceptual learning (Denner et al. 2014), increasing enjoyment (Liebenberg et al. 2012), and improving the quality of design, especially in complex tasks with novice programmers (Arisholm et al. 2007).

We designed a case study for K–9 education, where 4th grade students (N = 58) participated in an introductory Scratch programming course. The introductory course lasted for four months and was organized as one lesson per week. The participants formed dyads or small groups and programmed up to 14 different kinds of Scratch projects (Figure 3). All Scratch projects (N = 339) turned in by students during the course were collected as data and analyzed (Fagerlund et al. 2020). Additionally, student dyads were video recorded while they programmed their final open-ended and creatively planned interactive Scratch games or stories. The preliminary research findings from this case study (Fagerlund 2018; Fagerlund et al. 2020) highlighted known key interactional and socio-emotional issues, which are important for consideration in programming pedagogy. For example, a student, seemingly typically the "navigator," becoming detached from the shared programming process may be a result of a creative disagreement, a temperament mismatch among the collaborating students, established social roles, or an incidental effect caused by a dysfunctional organization of the "driver" and "navigator" roles. A distortion in the amount and quality of active participation in and decision-making regarding the shared problem-solving process (and thus, the thinking work required and potential learning) may be born. This can be manifested as, for example, inequity in the amount and quality of talk (e.g., more or less negotiating or one-sided decision-making when making creative decisions) (Lewis and Shah 2015). Also, our findings suggested that the physical environment, namely, the formation of desks and chairs, can either support or hinder the quality of collaboration in pair programming with Scratch at the primary school level (see also Ally et al. 2005).

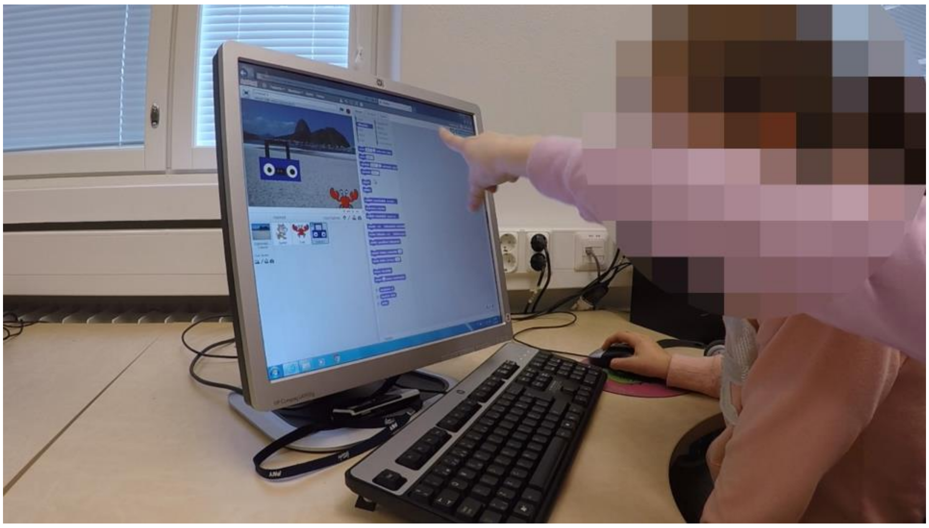

Figure 3. Students programming an open-ended Scratch project in pairs (Fagerlund, 2018)

Altogether, the weight of different kinds of factors influencing the quality of pair programming can be shaped by several elements in versatile learning contexts and the miscellaneous interactions of different people (e.g., peers and instructors) taking part in the learning process (Scherer et al. 2020). However, as elaborated above, the functional interrelationship of a collaborating dyad or a student group seems to effectively determine whether the programmatic problem-solving work and knowledge construction is truly collaborative or cooperative, or perhaps adverse to collaboration or cooperation, and whether it skews key elements, such as motivation, engagement, ownership, and agency, in socially emphasized learning contexts. An important question arises: How can teachers support primary school students' engagement and learning through meaningful participation in multifaceted and dynamic, creativity-focused and design-led pair programming processes? Another critical aspect in which social and socio-emotional issues display their importance is assessment. Can we entirely rely on the relatively common practice of assessing artefacts collectively programmed by several students as valid indications of each student's learning? Automated assessment by cognitive tutors that provide smart, timely feedback is gaining popularity in programming education (Moreno-León et al. 2015), and they hold the potential to support students' conceptual understanding in programming. However, a fundamental question is: How could the complex social and socio-emotional reality and students' engagement within a group be included in developing reliable assessment? The findings from this case example (Fagerlund 2018; Fagerlund et al. 2020) provide further insight regarding such questions in this relatively young but ever-growing research topic.

1.7 Discussion

This book chapter provides examples of the pedagogical and technological implementation of different emerging learning environments, namely, simulations applying VR/XR, constructing and exploring Vive/Minecraft environments and pair programming with Scratch. These environments have a great potential to function as support for collaborative learning and interaction (Jeong and Hmelo-Silver 2016; Rosé et al. 2019). How well people learn together when using these environments cannot be explained only by how they process information, but requires taking into account social and emotional processes: how learners interact, relate, and engage with each other, learning together as a group with the affordances of the learning environment (Baker et al. 2013; Ludvigsen and Steier 2019; Miyake and Kirschner 2014; Näykki et al. 2019). Emotional experiences and expressions are particularly recognized as an especially central resource of successful collaborative learning (Baker et al. 2013). The use of potential technological enhancements in collaboration necessitates an interdisciplinary understanding of the social factors and emotional dynamics influencing the learning and interaction processes (Järvelä et al. 2020). We argue that when affective interactions are more thoroughly accounted for and enhanced through technology, they can have positive implications for cognitively effortful and meaningful collaborative engagement, thus contributing to better competence building and participation in group work.

All these learning environments presented by our case examples provide opportunities for making learning and interaction more tangible and, in addition, afford teachers the possibilities to view ongoing learning processes and guide, support, and provide feedback accordingly. This, however, may be challenging when the teacher lacks the prior experience to implement such environments for learning. When the instructional goal is to provide possibilities for collaborative learning, teachers may need to learn how to organize and support collaborative processes and to flexibly adjust the degree of student responsibility (Nousiainen et al. 2018). Sometimes this may mean adding more structures and rules; however, it may also mean picking up the right moments, so-called teachable moments, and steering the process from there. For example, when spontaneous and self-directed activities emerge (such as when the groups began to build connections between their villages in the Minecraft project), it opens up an opportunity to address and discuss the learning content in a context that is meaningful and approachable for the learners. Furthermore, even though modern tools, such as simulators, are currently created for providing automated guidance and feedback for the learners, too often simulator feedback is not easily understandable and may require elaborating in a form of teacher feedback to make sure that the feedback is supportive for the training needs of the learner. The same can be seen with programming environments, where feedback often manifests as programmatic errors (i.e., “bugs”) without further explanation as to where the learners, drawing from their mental models, have made a mistake. Often, particularly in safety-critical contexts, technology cannot fully replace the need for real human interaction, given that these technologies need to be further developed to avoid misunderstandings and risks of not using failures correctly for learning purposes.

As we observed the clear benefits of VR simulations, there are also potential risks in applying VR technology in education. A recent survey by Kaminska et al. (2019) pointed out that one of the risks in VR education might still be the lack of flexibility. During traditional education, the student has more freedom in interacting with the natural environment, asking questions, discussing, and interacting with teachers. Further, VR headsets have their physical restrictions, even though these are developing towards lighter and more user-friendly versions. The role and importance of a social environment, teacher, or peer-learners should not be overlooked by over-relying on technology. There is too much focus being placed on hard skills over soft skills in, for example, workplace-related learning, which occurs with excessive focus on education technology and forgets human interaction, mentoring and teacher-student relationships (Kaminska et al. 2019). Vesisenaho et al. (2019) described how differently each student physiologically reacted in the VR experiences. However, we deduce that one of the key issues of VR simulations is preserving both their social and technological benefits, which can be achieved by integrating the principles of simulation pedagogy into VR simulation-based learning. Thus, the supportive role of guidance and building a common understanding in the learning situation is acquired, rather than leaving the teaching task to technology alone.

The use of simulators, game-based VR/XR environments and programming as arenas for pedagogical activities has motivational potential from the perspective of learning and teaching, providing interesting arenas for future studies. In creative design-focused, open-ended collaborative settings, such as in programming experiments, learners’ personal creativity-focused goals may need to be reconciled with shared goals. This requires generic collaboration skills, emotional intelligence, and argumentation skills. In general, new methods and approaches are needed to study social knowledge construction, as well as opportunities for adapting known methods (e.g., interaction and discourse analysis) to emerging technological contexts (e.g., creative coding and digital fabrication). A detailed analysis of the interaction between learners or the student and the teacher will offer information on the learners' engagement in a group task. Further analysis could also detect simulations' and teachers' roles in supporting students' engagement in a learning process. Likewise, an introduction to a simulation case, feedback given by the teacher, and joint discussions during the tasks, as well as a debriefing discussion, will provide possibilities to study the instructor's guidance and support of the student during a VR-enhanced SBL situation. One specific context for further research is teacher education. Teacher education students are in a key position to develop digital learning opportunities in their prospective teaching work (Häkkinen et al. 2017). Student teachers' motivational orientations in gamified learning contexts have been found to emphasize social interaction and altruistic purposes (Fischer et al. 2018; Nousiainen et al. 2020). Collaborative, immersive activities are likely to motivate these types of users (Nousiainen et al. 2020), and as these aspects are an inherent part of XR environments, we can expect them to be a meaningful learning context for student teachers as well.

As the corpus of available digital learning tools and environments grows, it is becoming all the more necessary to communicate the big picture of learning and interaction to educational practitioners, technology developers, and learners themselves. To improve learning, teaching and innovation, technology-based tools, such as *virtual reality simulations, gaming and programming,* should be designed and experimented to filter and open up opportunities, as well as to consolidate them into transferable ideas and processes that may be picked up and used as innovations between different user groups (Vesisenaho et al., 2017). Further, the outcomes of the cases presented here can be implemented in developing artificial intelligence that can automatically recognize and adapt to learners' and teachers' reactions and interactions, providing support during learning.

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