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University Students as Co-creators in Designing Gamification Teaching Activities using Emergent Technologies in Swedish K-12 Education

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Abstract. This paper reports on a study exploring the use of university students as co-creators when designing activities for an emergent teaching practice such as gamification, using emergent technologies in a Swedish K-12 education context. More specifically, the aim was to empirically explore and develop knowledge about the process of designing for gamification teaching in K-12 education, to develop gamification teaching design principles and, in addition, to study how emergent technologies could be used in this context. Four sub-studies were conducted between 2014 and 2018 which included four groups of university students as co-creators in the teaching designs. The empirical material is based on observations from the field test in which school students tested university student designs. Post interviews were conducted with participating school teachers and university students. In addition, university student written reports were included. Findings illustrate four themes; 1) *The design process of the gamification teaching activities, 2) The gamification teaching design principles developed, 3) The school students' experiences of the gamification designs* and *4) Designing gamification teaching activities – a complex process.* Findings show that designing for gamification teaching designs using emergent technologies is quite a complex process. This complexity concerns, among other things, the puzzle of combining the different knowledge domains into the TPACK Model (i.e. technological knowledge, pedagogical knowledge, content knowledge) in an emergent teaching practice (gamification) with the use of emergent technologies. The co-creation process and the move between these knowledge domain areas could maximize the effect of achieving a pedagogical balance concerning what school students perceive as fun without sacrificing focus on their knowledge acquisition and learning processes.

Keywords: co-creators, university students, gamification, emergent technologies, K-12 education, design processes

1 Introduction

Rapid technological and societal change and the ongoing digitalization of societies around the world impose new demands on education and what students should learn in school. This fast-paced technological development has impacted society, schools as well as the labour market, and research [1][2][3] shows that, in a digitized society, it is necessary to be able to think creatively, to collaborate and to solve problems together with others and to take advantage of the opportunities that digital technologies open up. In a study Dede [4] found that organizations (e.g. Partnership for 21st Century skills, the North Central Regional Education Laboratory, Metri

Group, OECD, the National Leadership Council for Liberal Education and America's Promise) have developed their own frameworks for the new millennium that delineate the content and processes teachers should convey as part of student schooling. Further, there is a problem as there is a lack of clarity on what these skills actually concern, what the concepts consist of and in which direction a digitized education should move. According to Dede [4] many educational reforms have failed, even if intentions have been good, because the same terminology is used but means different things.

Over the last years, there have been large scale one-to-one computing initiatives in Sweden, (e.g. one laptop or tablet per child) that have been implemented in compulsory schools. Despite these digitizing initiatives, research shows that teaching designs in Sweden [5][6][7][8] as well as in Denmark [9], are mostly organized through teacher-centered instructions which, to a limited extent, promote student-centered learning activities aimed at the development of student abilities to collaborate, reason critically, communicate, solve complex problems and use digital tools in teaching and learning (e.g. 21st century skills). In addition, there has been another challenge for Swedish teachers concerning how to interpret and implement the recently-implemented national digitalization strategy regarding the development 'adequate student digital competence' [10]. One of the challenges for teachers concerns how to interpret what this adequate digital competence really means and how to implement and use digital tools in the classroom. Further, the concept of what adequate digital competence is or could be is not defined in the said strategy.

Koehler, Mishra and Cain [11] argue that teaching in a technology-rich school environment requires an interweaving of specialized knowledge of both *content* to be taught, *pedagogy* and *technology* (e.g. TPACK,). They argue further that school today is an ill-structured organization concerning teaching with technology. Effective teaching using technology depends on flexible access to rich, well-organized and integrated knowledge from the different knowledge domains. For teachers it may be perceived as both challenging and time-intensive and an activity that has to be fitted into an already busy schedule in order to acquire a new knowledge base and skills on how technology can effectively be used in teaching [11]. Consequently, teachers face challenges that concern how to design for teaching and learning in a technology- rich learning environment and, in turn, which teaching designs are useful for developing these skills and student digital competence. Another challenge for both teachers and students concerns teachers' relatively traditional approaches to teaching and learning even if technology is used in the classrooms to a somewhat higher degree [5][6][7][8][9][12]. Reports from the Swedish School Inspectorate [13][14] also show that despite technology-rich environments, Swedish students lack motivation for doing schoolwork [13][14]. A Danish study [15] suggests that teachers often convey fairly traditional understandings of creativity and innovation, which limit student ability within open-ended learning processes. Further, research has also shown that gamification teaching designs using contemporary and emerging technologies [16][17] could be valuable tools for developing student abilities to collaborate, reason critically, communicate, solve complex problems and use digital tools and, in turn, develop their digital competence as these teaching designs pose engaging and complex challenges which foster problem-solving, collaboration, knowledge sharing, creativity, construction and strategic thinking. However, previous research [18][19][20] has found that teachers possess limited knowledge about emergent technologies and what gamification teaching design is or could be. In addition, school teachers lack knowledge on how to plan, design and organize teaching using emergent technologies and gamification teaching activities in the classroom [21].

The aim of this study is three-fold. First, to empirically study and develop knowledge about how university students are able to act as co-creators and to examine their design process (e.g. from first idea to implementation in the classroom) and to develop gamification teaching design principals for K-12 education in order to support school students when developing their 21st century skills and digital competence. Secondly, the aim was also to study how emergent technologies could be used in this context to enhance student knowledge acquisition and learning processes in K-12 education and thirdly, the aim was to record the experiences of the school students and teachers participating.

Research Questions:
RQ 1: How can university students act as co-creators designing gamification teaching activities for K-12 education?
RQ 2: What gamification design principals did they develop?
RQ 3: What are the experiences of the school students and teachers?
RQ 4: What opportunities as well as challenges are there when using university students as co-creators designing teaching activities for K-12 education?

2 Background

Current rapid technological development and the implementation of 'new' emergent digital technologies in education for teaching and learning purposes is increasing. In research [22][23], this is categorized as emergent technology and emergent teaching and learning practices. The term *emergent* is often used in a context where the concept of 'new' technologies is regarded as tools, concepts, innovations and advancements [22]. Hence, the understanding of digital technology is intentionally broad and includes tools and software as well as concepts such as didactical design or technology-enhanced teaching and learning. The definition of emerging technologies concerns five attributes: radical novelty, rapid growth, coherence, prominent impact plus uncertainty and ambiguity [24]. A technology could therefore be understood as being emergent if it is regarded as neither a must-have nor is often used in educational practices. For example, augmented reality technology (AR) and virtual reality technology (VR) are defined as emergent technologies even though they are not yet widely adopted technologies in education [25]. Veletsianos [22] describes emergent technologies as expected to substantially influence current and future educational practices and exert an expected magnitude of impact. Moreover, emergent teaching practices (for example gamification or the flipped classroom), are teaching practices that involve experimentation and openness and the ability to respond to changing circumstances in the ongoing digitalization of education [23]. Further, Knight [23] describes emergent teaching practices as that they are understood as embracing unforeseen benefits where educational practices are moving towards changes of approach and to more collaborative ways of working. Both emergent technologies and emergent teaching practices are regarded as shifting and changing over time [22].

2.1 Learning Expeditions – an Emergent Teaching and Learning Approach

Debates on how to 'best' design for teaching and learning in schools and its effects on student learning have been discussed for decades and, for example, scientists such as McLuhan [26, p. 100] stated back in the 1960s that "education must shift from instruction, from imposing of stencils, to discovery - to probing and exploration and to the recognition of the language of forms". In line with what McLuhan [26] claims above, Jahnke [27] argues that education and teaching in a digitized school must develop something she calls *Learning Expeditions*. This teaching strategy is all about giving pupils an opportunity for self-reflection to a greater extent and giving students an opportunity to be able to make independent decisions in their learning process. This type of teaching strategy, where students are allowed to be exploratory in their knowledge and learning process together with a well-planned digitalized teaching design, promotes student engagement, curiosity and motivation for school work [27]. Furthermore, Jahnke argues that creative teaching designs using digital technology is closely linked to student-centered teaching, autonomy, playfulness and creating new artifacts. Jonassen, Howland, Moore and Marra [28] believes that student use of technology in learning can benefit their knowledge acquisition and learning processes when technology is used for complex problem solving and information retrieval. In order for students as to be able to acquiring knowledge effectively and learn with digital tools as support, teaching designs must change from traditional teaching practice to a more constructive approach when it comes to student-centered learning in order to achieve what they call meaningful learning. Jonassen [29] argues that students can only achieve efficiency in their learning process when they are allowed to construct knowledge, think and learn through their own experience, preferably together with others. In a study by Kim, Kim, Lee, Spector and DeMeester [30], they found that teachers' own knowledge vision (e.g. teacher beliefs) influenced their way of teaching using digital tools. In Ejsing-Duun and Skovbjerg's study [15] they found that student opportunities for discovery learning processes are limited by teachers' often traditional understanding of creativity and innovation in their teaching design. Kim et al. [30] argue that teachers using digital tools will not change unless teacher knowledge views change. They further argue that teachers need a lot of support to increase levels of technology integration into teaching in order to really change their teaching methods, e.g. more towards digitized gamification teaching design.

2.2 Gamification - an Emergent Teaching Strategy

Gamification as a concept is on the rise within various industries and businesses where perhaps the industry is at the leading edge and utilizes the concept for competence development of staff [31]. In a report from 2015 on trends and challenges for Scandinavian schools, gamification was predicted to enter the Swedish school system within 3-5 years [25]. Recurring reports have pointed to similar results however not much has happened, at least not in Sweden. The use of gamification teaching design in school therefore aims to increase student motivation and commitment to school work in order to promote learning processes and knowledge acquisition in order to improve their school results. Sailer, Hense, Mayr and Mandl [32] define gamification as processes to make activities in non-game contexts more game-like by using game design elements. The purpose is to try to recreate what Csíkszentmihályi [33] describes as the "flow experience" where students are engaged and focused in the learning process and with full energy and motivation concentrate on a school assignment (cf. gaming). "The flow" is the component that guides every well-designed activity. However, Albertazzi et al., [31] show that in order to achieve the desired effect, gamification teaching activities and tasks must be designed with a level of complexity that corresponds to the knowledge and skill sets possessed by the students. The assignments must be sufficiently challenging but must not be too difficult or too easy to solve. One example of a teaching design that touches on gamification with the purpose of motivating and engaging students in the learning process is to create problem-solving tasks with content that students can solve in groups that in turn lead to new clues for new problem-solving tasks to solve which then leads to a final problem to find the solution to. The winning group can be then be crowned, like a treasure hunt [18][19][21].

However, the few studies there are available in this field show that the desired effect is strongly dependent on the current context, how teachers plan and carry out the teaching and on the students participating [17][24][31][35]. Although research show considerable effects with regard to pupils being given increased motivation and commitment to school work by using gamification teaching designs, Landers and Armstrong [35] argue that if it is only used as a trendy design for the popularity to increase, then the intended effects may not occur. Furthermore, they feel that students with attitude problems or students with little experience of this type of teaching may prefer traditional teaching to gamification teaching designs. Students are, of course, not a homogeneous group and using the same approach for everyone in all teaching situations may be ineffective [31].

According to the Swedish Media Council [36], 99% of Sweden's teenagers have access to a smartphone, 86% of 9-12-year-olds use smartphones to play games and 38% play daily. However, the frequency of gaming between girls and boys differs. The greatest difference can be found in the range 13-16 where 47% of the boys play daily while the corresponding figure for the girls is only 4%. Concerning the younger children's media habits [36], 58% of 2-4-year-olds play digital games. 80% of 5-8-year-olds mainly use smartphones or tablets for games and 51% of 8-year-olds play every day. Thus, gaming has an enormous impact on children and young people, but how this affects teachers' readiness to use game mechanisms and game dynamics in their teaching design and what effect they exert on student learning and motivation for school work is unfortunately an unexplored area. Regardless, this is something that the school should and must handle in one way or another, but the degree of teacher readiness for this is low [18][19][21].

3 Study Context and Participants

Since it is really difficult to find teachers in Sweden who use gamification teaching designs continuously as a teaching strategy, a decision was taken to conduct a study inspired by design-based research methods [37]. In order to be able to study the entire process i.e. from the first idea to the teaching designs created and then to the operationalisation [38] in the classroom, an opportunity came up to cooperate with a mandatory course given within two Master of Science programmes for engineering students at Umeå University. The purpose was to have the university students act as co-creators and design gamification teaching activities for school students. The purpose was as to be able to use their creativity and technological competence to develop *examples* of gamification teaching activities using emergent technologies in a school context. The aim was thus to be able to go beyond ordinary classroom teaching (i.e. think outside the box). The students participating in this study undertook a mandatory course on '*Planning and organization work in a project*' within the Masters of Science in Engineering Physics and in Industrial Engineering and Management. The university students could be described as *co-creators* for the four design-based sub-studies presented below.

In summary; four sub-studies were conducted between 2014 and 2018 and included in this design-based research project (See Fig. 1). In each sub-study, 3 students studying Master of Science in Engineering Physics and 3 students studying Master of Science in Industrial Engineering participated. They worked together as a mixed group. One group of six students each year in 2014, 2015, 2016 and 2018 (i.e. 4 sub-studies). In total there were 27 university students who participated in the research project (i.e. one group of six students in each group each year). In addition, a group of 3 students studying Interaction and Design participated in Sub-study 1 in 2014. The four sub-studies could be characterized as constructing four *examples* of gamification teaching designs in combination with the use of emergent technologies. Each group of university students in each sub-study were given almost the same task, namely to develop a gamification teaching activity for school students using emergent technologies in the teaching design. It was only the content (i.e. the subject taught by the participating teacher) that differed and to some extent the emergent technology used. The researcher responsible provided an open situation, a school environment and supported the university students along the way. They also received support from the relevant school teachers. The school teachers participating also suggested the topic for the gamification teaching designs, except in Sub-study 1 where the topic was determined by the university students.

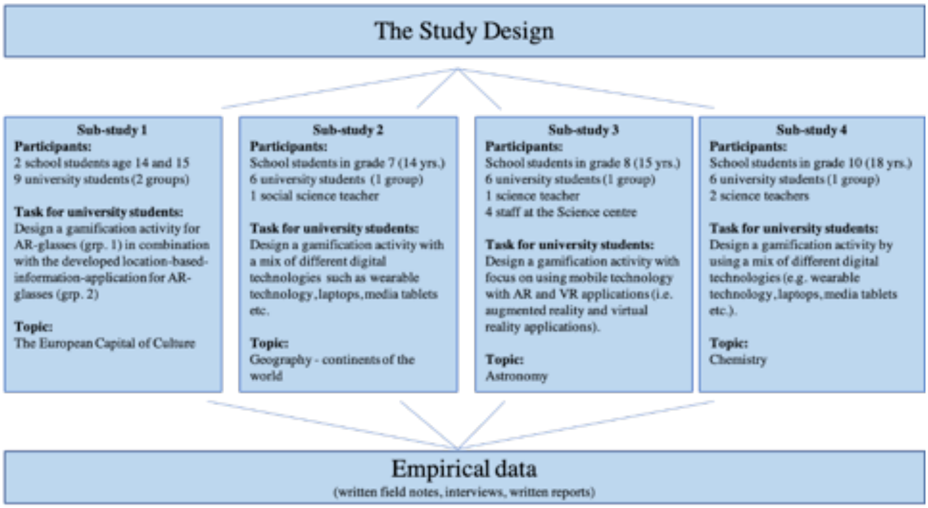

Fig. 1. Study Design

4 Methodology and Methods

A qualitative approach was taken in order to be able to explore and deepen the understanding of how university students are able to act as co-creators in a design process and the requirements within the design process for gamification teaching in K-12 education. The empirical material was collected through observations (n=4) during the field tests with the school students, semi-structured interviews with all the university student groups (n=4) and semi-structured interviews with the teachers (n=4). In addition, the university students' written reports (mandatory for them in the course they took) from each sub-study were also included in the empirical material (n=4). All participants agreed to a statement of research ethics based on beneficence, non-malfeasance, informed consent and confidentiality/anonymity [39].

The semi-structured interviews with the university students focused on their own experiences and actions taken as co-creators regarding their design process from idea generation to the actual developed framework of gamification design principals and then to specific gamification teaching designs. For example, the interview guide consisted of several open questions such as "*Tell me more about your how you planned, designed and organised this activity*" and "*What was your first idea and how did you choose which technology to use in which activity*?". The teacher interviews also consisted of a semi-structured interview guide with open questions in 4 areas such as their experiences from the field test, their views on using gamification as a teaching strategy in teaching and learning, what is required of teachers when designing for gamification teaching activities concerning opportunities and challenges and competence development and finally, their advice for teachers who wish to use gamification as a teaching strategy. The school students' experiences were collected during the field tests by taking written field notes of observations and of discussions with them during the tests, for example, in order to clarify a chosen strategy within the group or what they meant by something they said. After each field test the university students gathered all the school students for an oral evaluation in which the researcher took written field notes.

5 Theoretical Framework

The theoretical framework for this study is based on Leontiev's [38] Activity Theory and his concepts of *motives*, *goals*, *actions* and *operationalisation.* Activity Theory allows the exploration of a context in relation to tools used, social relations and materials and the intention of the planned activity. In addition, the interplay between these aspects and how they affect actions in different situations may be explored. Using the framework of activity theory, the focus is not only on an individual's actions but also on group actions in relation to an activity system. In a context where activity theory is used it is also important to study the role an artefact or a tool plays in the activity system [40]. Leontiev [38] explains that an activity, which he sees as a system, includes elements of motive, goals, actions and operations. For example, in education the teachers carry out operations in the classroom (e.g. teaching). The operations could be, for example, different routines, procedures or practical examples of a topic and this in relationship to the preconditions within the school organisation. The different routines, procedures or practical examples are made up of combined *actions*. These are, on the other hand, related to a goal the teachers are trying to pursue (see Fig. 2). In this study, the four sub-studies are regarded and analysed as four activity systems within a larger activity system.

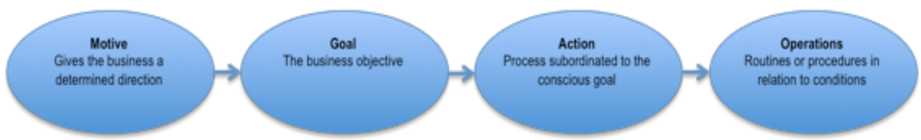

Fig 2. Key concepts in an activity system according to Leontiev [38].

Hence, activity theory is used as an overall framework for the study but not used as a specific analysis tool for the empirical material collected. For example, activity theory frames the overall study in different levels concerning the *motive* which is exploring how university students are able to act as co-creators in order to develop school students' 21st century skills using gamification teaching designs using emergent technologies. The overall goal is to develop different examples (e.g. design principals) of gamification teachings designs by using university students as co-creators (4 sub-studies included). *Actions* taken in the study concern examining the university students' design processes. Finally, their gamification designs and the gamification principals they developed were tested out in the field concern the concept of *operationalisation.* In addition, within each sub-study, the concept of motive concerns the purpose (e.g. motive) of the specific sub-study regarding the teachers' chosen topic and what the school students should learn about the chosen topic and the goal concerns a design that focused on developing the school students' 21st century skills and the specific use of emergent technologies. The operation concerns the testing of the university students' gamification teaching designs by the school students.

This study is inspired by and includes aspects of design-based research methods [37] and could be described as being of an exploratory nature.

5.1 The Analysis Process

In order to identify key themes and emerging patterns within the theoretical framework of Activity Theory [38] and in addition, to be able to construct an understanding and a meaning of the empirical material, thematic analysis [41] was used. Using thematic analysis in qualitative research could be described as an analysis process for encoding qualitative information. Thematic analysis can thus be used to assist the researcher in the search for insight [42]. Boyatzis describe the process as including two perspectives – 'seeing' and 'seeing as' and Creswell [43], explain the 'seeing as', as that of searching for repetitive patterns of meaning (i.e. significance) in qualitative data. This process includes several readings as part of iterative processes for identifying emerging patterns. The various steps include for example a) reduction of the data (coding), b) presentation of the data (thematisation) and c) summation of data in the form of conclusions and verification. According to Ely [41] a theme could be described as a definition of either utterances that all informants in a study express or as a single statement of an opinion that has a great emotional or actual significance. In this study, the phase 'seeing as' (constructing meaning) was carried out by searching for signs and patterns at a more abstract level regarding participant utterances in what they were explicitly or implicitly saying in interviews. The empirical material for the university students' design processes consisted primarily of their written reports and the interviews with all the university student groups after the field tests in each sub-study. The emerging themes from the reports and interviews were then analysed in combination with the written field notes (e.g. triangulation). The data from the empirical material was first coded into emerging categories (e.g. motives, goals, actions and operationalisation), and then into emerging themes within each category. For example, what the university students stated that they wanted to achieve with their design (i.e., *motives* and *goals*) and what their strategies were during the design process and how they organised and implemented their intentions (i.e., *actions* and *operationalisation*). The emerging themes in the material as presented in the next section of findings were thus derived and formed during several iterative analysis processes.

The quotations in the Findings section below should not to be regarded as evidence, but more as illustrations of the themes that emerged in the empirical material analysis process.

6 Findings

Findings are presented in four themes. The first theme concerns the university students as co-creators for gamification teaching activities for K-12 education. The process of co-creation describes the creation of the first idea all the way to the actual operationalisation of the field test. The second theme illustrates the university student gamification design principals and the third theme regards the school students' experience and their own perspectives on the gamification designs tested. The fourth theme, concerns the complex process of designing for gamification teaching activities using emergent technologies in K-12 education.

6.1 The Design Process of the Gamification Teaching Activities

In all four sub-studies the university students were undertaking a mandatory course of 7.5 higher education credits in their programme on project management. The course lasted one term, part time at 25%. In this study they were given an assignment from the researcher to act as co-creators for designing a gamification activity for school students. The researcher was not involved in the university course nor in the engineering programmes. The university students had a supervisor as their teacher for the course and they received feedback along the way on their design process as well on their work as a group in a project team. The university students had attended several mandatory theoretical lectures on design processes and project team work in general. However, the content of their courses was not about gamification or game-based learning and nor were their lectures. This was, so to speak, new content and focus for both the university teachers teaching in the course and the university student groups. The researcher in this study guided the university students on the assignment given (i.e. design-based gamification activity) to help them act as co-creators and to stay focused on its intentions and goals. The researcher also gave feedback on their design process along the way and on the results of the field tests with the school students at the end of the term.

Since the university course focused on how to conduct and design a project, the students had to read literature about design processes and hand in associated assignments to their teachers on their project work. For example, they had to submit a requirement specification for the project at the beginning of the term in order to narrow project scope in order to make it more feasible.

The university student design process in all four sub-studies could be described as divided into seven steps; 1) preparing a requirement specification of the assignment 2) theoretical studies of gamification as a concept 3) conducting interviews with school students to gain information about school student habits and use of technology in everyday life and knowledge about and use of games and gaming habits 4) interviews with school teachers about how to adapt to students age and knowledge level in the topic given 5) idea generating 6) concept construction 7) final tests (see table 1).

Table 1: Different steps in the university students' design process

Students' design process		
1.	**Requirement specification**	From the assignment given by the researcher the students prepared a specification of all the requirements for the project. This also included areas not to focus on during the project in order to narrow the scope. The students received feedback from their supervisors (university course teacher) and sometimes had to re-write the specification to make the project plan clear.
2.	**Theoretical studies of gamification as a concept**	In order to gain more knowledge about what gamification is and for what purposes gamification could be used for, the students search for articles and studied the Ocatalysis Framework. They also search for information online by themselves as concerns practical examples of gamification activities in school.

3.	**Interviews with school students**	In order to gain more knowledge about how school students use technology in their everyday lives and how they use games and their gaming habits, the student conducted interviews with school students. These were not the same school students who participated in the final test.
4.	**Interviews with the school teacher**	In order to be able to adapt the knowledge level of the topic given for their gamification teaching designs, the students interviewed the relevant teachers. Once during the process, each school teacher also gave them feedback on their planned designs in order to identify the right level of knowledge on the topic given. Especially as concerns difficulties with questions, problems to solve and challenges.
5.	**Idea-generating phase**	When knowledge was gathered about both the concept of gamification and after the interviews with school students and teachers, the university students began their idea generating phase. All the four university student groups used different tools and activities as support to brainstorm ideas. They obtained inspiration from some of the lectures in their design process course. For example, Group 1 used the 6-3-5 method of brainstorming. The 6-3-5 method is a written activity where all participants have a page consisting of 3 columns. In each column, they wrote their idea. After five minutes the page moved to the next participant who could then build on the previous idea. After this session the students structured all the ideas by grouping them together (see Fig. 3).
6.	**Concept construction**	After the idea-generating phase the students began on the concept construction of their own framework focusing on the topic given. This meant focus on what the school students had to learn about and then divide this into stations/challenges and different levels towards the final question/challenge (see description in the next section). For example, Group 3 chose to divide their topic of astronomy into four parts/stations (planets, space station ISS, landing on Mars and gravity) along with a final challenge for the school student groups to solve. University student Group 3 also constructed a general framework where teachers could divide a topic into 3, 4 or 5 parts (se description in the next section). For their own activity in this study they chose to divide the topic into 4 parts.
7.	**Final field test with school students**	In all the sub-studies the university student groups tested their gamification teaching design at the end of the term on school students as a field test. Each test was then evaluated orally by the school students and the relevant teacher.

Fig. 3. An example of collection and structuring of ideas for the gamification teaching designs by university students in Sub-study 1.

6.2 The Gamification Teaching Design Principles Developed

6.2.1 The First Sub-Study in 2014. The first sub-study was conducted in 2014. In this particular study the focus was on exploring how to combine an emergent teaching practice (gamification) with the use of an emergent technology (Google Glass as the one of the first consumer AR glasses). 9 university students participated as co-creators for the design and they were divided into two groups. In addition, 2 school students aged 14 and 15 participated. They so to speak 'tested' the university students' design. One of the university student groups (Group 1 = 6 students) were assigned the task of creating a gamification teaching design for the two school students and, in addition, combining this activity with a location-based information application that the second group of university students were developing for the AR glasses Google Glass (Group 2 = 3 students studying Master of Science Programme in Interaction Technology and Design). The application was developed from location-based information for the smart glasses, pushed information to the smart glasses and the school students received messages or information (i.e. clues) when they approached different locations in the field test.

Since Umeå was the European Capital of Culture in 2014, a culture theme was chosen as the content of the gamification activity. Further, a requirement for Group 1 who created the gamification activity was also to develop problems or challenges in which the school students would be able to collaborate, reason critically, communicate and solve complex problems (i.e. 21st century skills). These students chose to develop a treasure hunt where the school students had to solve different problems and challenges before getting the next clue etc. The school students had thus to complete one level before being able to move forward to the next level. In gaming this is known as *levelling-up*. Due to limitation on access to the smart glasses, the two school pupils got the chance to borrow these for this specific activity in the field test.

The two school students had to collaborate during the entire treasure hunt. They also had to solve the given problem/challenge at each level. This meant that they needed to put pieces of information together that was pushed to their specific Google Glass (using location-based information) and put these information pieces together to be able to solve the challenge. This could be described as solving a puzzle of information. Sometimes, the school students had to discuss what the correct result could be in order to get the clue necessary to reach the next level (see Fig. 4). This 'game' could be compared to stepping into a virtual game but was conducted in real life. Hence, this was a gamification treasure-hunt activity (see design example in Fig.

5) in combination with the use of the smart glasses where pieces of information were pushed to the glasses by using location-based information.

Fig. 4. In this scene the school students were discussing the pieces of information they got for one challenge and how they could solve the clue.

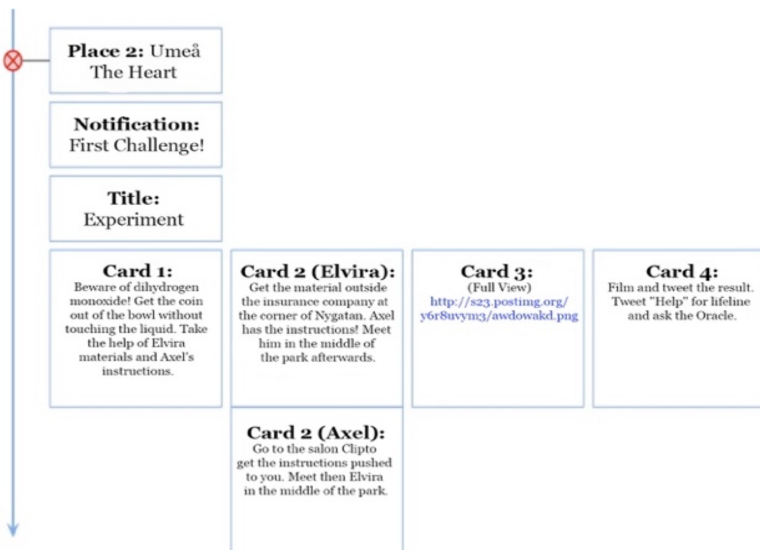

Fig. 5. One pedagogical design example of the gamification teaching activity in Sub-study 1.

6.2.2 Sub-Study 2 in 2015. The second sub-study was conducted in 2015 using almost the same approach. This group of university students were also assigned the task of developing a gamification teaching design for school students. This time they were asked to design an activity where school students had to use a mix of different digital technologies (wearable technology, laptops, media tablets etc.). In this second sub-study 6 university students, one school teacher and 26 school students in Grade 7 participated (14 years old). In addition, the task for the university students was to develop problems/challenges in which the school students would be able to work in groups to collaborate, reason critically, communicate and solve complex problems (21st century skills). The school teacher participating (a social science teacher) determined the topic for the gamification teaching activity. Hence, the university students were tasked to create a gamification teaching module in geography; more specifically the continents of the world. This group of university students also created a treasure hunt, designed as a station system. The school students worked in groups and responded to a number of questions related to a specific continent to gather clues. Different types of technology were used at the stations in the form of Google Glass, virtual games, videos and audio clips. The school students collected clues at each station and these clues were to be used in the final round to identify a specific geographical location. During the treasure hunt, the school students used a tablet in each group to record the answers to each of the problems/challenges.

In this second sub-study the university students were introduced to Yu-Kai Chou's [44] framework *Octalysis* (see Fig. 6) in order to be able to extend knowledge acquisition for the school students during the 'game' so that the focus was not merely on having fun. The purpose of a gamification activity is to foster the inner motivation to solve a given assignment (i.e. level-up). Helping the university students to try to achieve this and support them in their creation of the gamification activity they were thus provided with the Octalysis Framework [44] as support in their design process. The Octalysis Framework represents 8 core drives that were used in the activity design process (see Fig. 6).

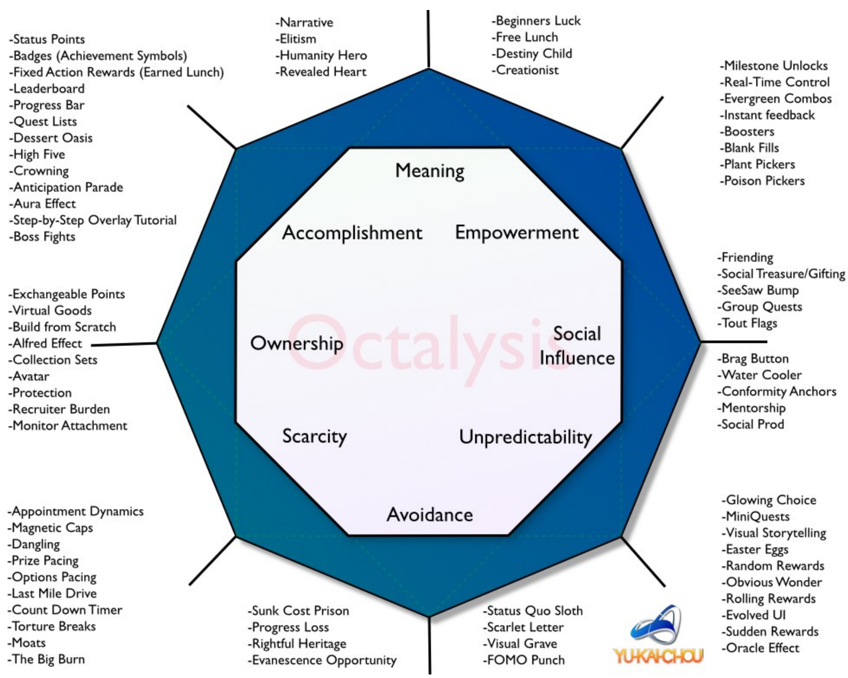

Fig. 6. Octalysis Framework – a gamification framework developed by Yu-Kai Chou [44].

The top three words in this framework (see Fig. 6) are, *Accomplishments*, *Meaning* and *Empowerment*. These are considered as positive driving forces. The three lowest words in the figure, *Scarcity*, *Avoidance* and *Unpredictability*, are considered to be negative forces. To the right the driving forces *Empowerment*, *Social Influence* and *Unpredictability* are presented. They are more emotional driving forces while those to the left, *Accomplishments*, *Ownership* and *Scarcity* are more physical driving forces. A fair balance between these should help to improve the experience in gamification teaching design, according to Cho [44].

Using the Octalysis Framework as a basis and the task given to gamify a teaching module in geography about continents around the world, the university students started idea-generating and produced a concept. In order to be able to organize the treasure hunt for all the school students at the same time, they developed their own concept as a framework (see Fig. 7). The structure (the concept) was divided into 6 stations, one continent represented at each station; Europe, North America, Africa, Asia, South America and Oceania (see Fig. 7). In order to be able to test and apply their concept and organize the treasure hunt for the school students, these were also divided into 6 groups and each group started the treasure hunt on a different continent. In the first part (top of Fig. 7), the school students received three easier alternate questions at each station that gave them 1-2 clues depending on their number of correct answers. One clue if one to two answers were right, and two clues if three answers were right. These clues helped the school student groups to proceeded to the second part of the treasure hunt which consisted of more complex problems to solve. Each school student group visited all 6 stations. When they had completed the second part at all stations they were given a clue to use in part three which consisted of a final problem/challenge. The final challenge was to place a specific city on a world map. One of the school student groups placed the city exactly on the right spot on the map, which in this case was Buenos Aires, and hence, won the game.

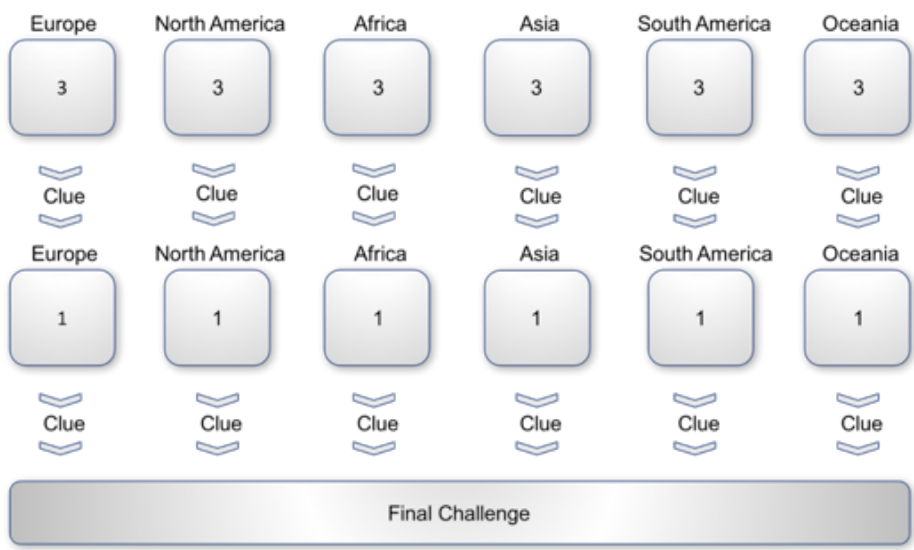

Fig. 7. The structure developed by the university students for the treasure hunt in which the numbers represent problems/challenges to solve at each stage at each station.

Each station represented a continent, and an augmented reality app was used on a tablet to scan different images for extra information linked to the problems/challenges (in this case the Layar Application). In some cases, they were information films about the continent at the specific station. The university students had designed simple games for the school students to play at some of the stations. For example, one game they had to link South America's countries and their flags with a map of South America. In addition, two different puzzle games were designed by the university students. In the last final challenge, the school students then had to place a specific city on a map that was the right answer to the final problem. This application consisted of computer software that measured the exact distance in kilometers from the place where the school students placed their answer on the map. They could only see the names of all the world's countries on the map, and therefore could not see or read where the specific city was located.

6.2.3 Sub-Study 3 in 2016. In 2016 the thirds sub-study was conducted. This time with a third group of university students. As in the previous groups, this group of university students were also tasked to develop a gamification teaching activity. An innovation was that they were instead tasked to focus more on using mobile technology with AR and VR applications (i.e. augmented reality and virtual reality applications). In this third sub-study, 6 university students, 1 secondary school teacher, one class of Grade 8 students (15 years old) participated and, in addition, the teaching staff at the local science centre. The gamification activity was thus tested by the Grade 8 school students. The university students received *Astronomy* as a topic for the gamification activity since both the teachers at the science centre and the secondary school teacher wanted to develop their own teaching in astronomy as regards how to use digital technologies in teaching designs.

The third group of university students was also introduced to the Octalysis framework [44] (see description above in Sub-study 2). The university students began their own design process by developing their own concept of the gamification activity by studying the Octalysis Framework [44] as a foundation. In this study, the university students developed a concept consisting of 4 sub-contests and the gamification activity ended up with a final contest. It was determined that the school students should use a media tablet in each group as a ‘hub’ due to how it enabled the involvement of all the school students in each group at the same time (easy to carry around and to interact with and to discuss with each other while looking at the screen). In addition, several other mobile technologies were used such as VR glasses and AR glasses (e.g. VR glasses using smartphones and Google Glasses).

The university students used an agile working process and after the first planning session they constructed a Gantt chart to provide a graphical illustration of their planned activity and to coordinate the tasks allocated in the project. The university students decided to divide the gamification activity into 4 parts/stations and after brainstorming they selected the best ideas for each part and, in addition, a final solution for each part/station. The topic for the gamification activity was, as earlier mentioned *Astronomy*, and themes for each part/station were established as 1) planets in space, 2) International Space Station ISS, 3) landing on the planet Mars and 4) gravity and lastly, 5) a final quiz where the questions were based on the themes in all four stations. This design enables them to collect direct feedback on what the students had learned during the activity and as a quick evaluation from the school students. At each station, points were awarded according to achievement and the school students could constantly, during the ‘game’, compare their own and other group scores on bar charts in Excel that appeared on a large screen as ‘live-score’ during the field test.

6.2.3.1 The Framework Developed for Sub-Study 3. The university students in Sub-study 3 developed a general framework as a concept to use when designing a gamification teaching activity. Their framework consisted of 6 steps intended to support a design process (see Fig. 8):

1) Find a theme for the topic to be covered. Examples for themes could be space, countries, chemistry or water etc.
2) The larger themes can be divided into 3 to 6 specific areas depending on the complexity of the theme or number of students participating (see Fig. 8).
3) Make a map consisting of the specific areas so the participants can follow their progress. On the back of the map a picture of each specific group avatar could be placed in order to create group unity.
4) Try to make the complexity of every area as similar as possible but, at the same time try to vary different problems/challenges and the use of technology in each area as much as possible. Interdisciplinary themes are the key to stimulating different individual's involvement and knowledge in order to strengthen the entire group's knowledge. During the game, as each area is presented, try to put questions about the most important thing which will be used in the final. It may be anything from something they have used during the specific task (e.g. station) to something they should learn anyway. When all the steps are completed, a score is also given for each step that should be equally important.
5) The final may be a quiz in which new knowledge from the different areas/stations can be tested as problem-solving tasks.
6) The last event is to present a live-score on a bar chart on a large screen.

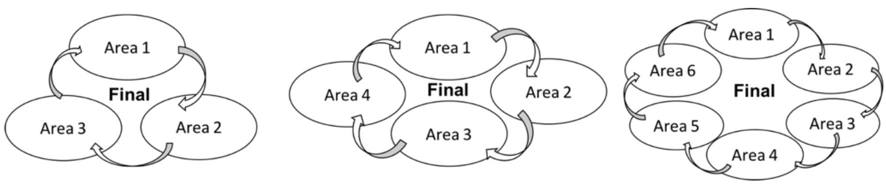

Fig. 8. The development framework to support a gamification teaching design process.

6.2.4. Sub-Study 4 in 2018. The fourth sub-study was conducted in the spring of 2018. This group of university students (n=6) received the same task, i.e. to create a gamification teaching activity. This time in the subject of chemistry. Six university students, two school teachers and 24 school students in upper secondary school (Year 10) participated. As in Sub-study 2, the university students were tasked to create a gamification teaching design by using a mix of different digital technologies (e.g. wearable technology, laptops, media tablets etc.). The topic for the gamification activity was organic chemistry (i.e. genetic information flow and metabolism, structure and function of enzymes and proteins). As in the earlier Sub-studies 1-3, the task for this group of university students was to develop problems/challenges in which the upper secondary school students would be able to work in groups to collaborate, reason critically, communicate and solve complex problems (i.e. 21st century skills). This group of university students was also presented to the Octalysis framework [44] (see description of the Octalysis framework in Sub-study 2).

The university students created an activity where the topic of chemistry was divided into six areas/stations featuring different planned activities. The first station consisted of a film and questions to answer, the second and third stations consisted of two types of quizzes. The fourth station was a Pictionary-like game in that a student was to draw a word connected to the subject and the rest of the group were to guess the word. The fifth station was about finding different elements by using VR glasses and VR applications for smartphones. At the sixth station the school students had to used AR glasses (Microsoft HoloLens) to see molecules in 3D (see Fig. 9). The school students were also divided into six groups consisted of 4-6 in each group. Points were gathered based on how well they succeeded at each station. These points were then merged into a single result. The school student groups completed one station at a time.

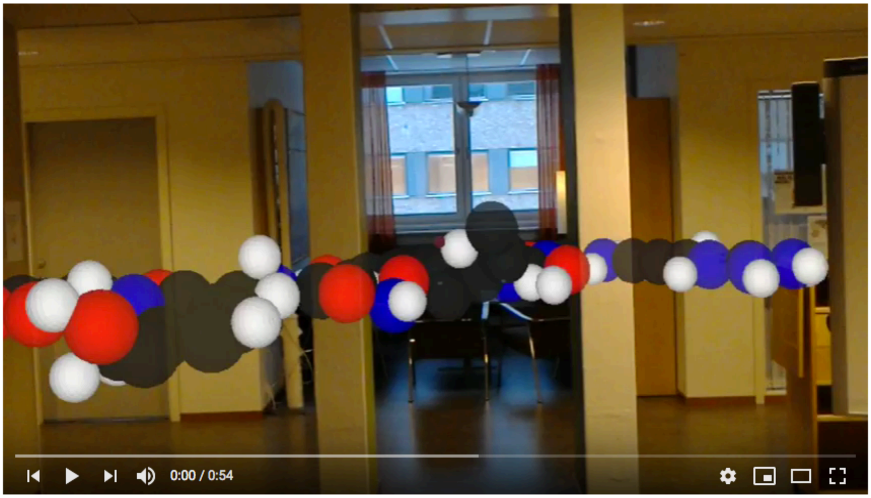

Fig. 9. A projection of a 3D protein molecule through the AR glasses (Microsoft HoloLens).

6.3. School Student Experiences of the Gamification Designs

There is no doubt whatsoever that all the school students participating in the four field tests liked the university students' designs a lot. The school students mentioned this in all of the four sub-studies. They thought it was fun and entertaining. They also mentioned that they wished they could have more of this in school. One girl in Sub-study 1 burst out after the test: *"This has been the most fun I have ever had at school, every school day should be like this one"*.

According to the observation notes, the school students were all eager to solve all the challenges/problems the university students had provided them with and showed great enthusiasm. They also used jagged gestures when discussing during the tests. During the entire activity, the school students stayed focused and collaborated in each group. It was also obvious that they developed their own strategies within the different groups. These strategies concerned, for example, figuring out which individual's skills and knowledge in the group were the best for solving a certain problem. They did this by discussing and deciding which one could solve the challenge/problem the best, especially at the stations that required only one of the members of the group. This was an emerging, repeated pattern in all of four sub-studies. The school students focused on collaboration in order to win the game. The teacher in Sub-study 3 confirmed this by stating during the interview:

> *"There were some of my students in some of the groups who discussed the answer to the clue intensively with each other and they were actually collaborating. Usually they don't talk to each other in the classroom. It seems like they forgot that." (Teacher, Sub-study 3).*

One interpretation could be that the game mechanics and game dynamics used in the university students' gamification designs, to some extent activated and fostered school student motivation to solve the problem/challenge by all means necessary. The activation and the use of game mechanics and game dynamics in the teaching designs could thus foster collaboration among students to a greater extent. Especially, if the teaching activity is designed to do just that.

6.4 Designing Gamification Teaching Activities – a Complex Process

One challenge for the university students was to adapt the content of the questions and problems/challenges in each part to a knowledge level suitable for the school students' ages and preunderstanding of the topic. Even if all the university student groups in each sub-study received feedback on the content produced (questions and constructed problems/challenges) from the school teachers, some parts/stations were perceived as too hard or too easy to solve. For example, in Sub-study 4 one school student said in the oral evaluation afterwards (chemistry class Year 10, in upper secondary school): *"I thought it was a lot of fun and motivating. Though I knew a lot before so the problems weren't that hard to solve".* Another student said: *"Some questions were too hard to understand and find the right answer at some stations".* This was also confirmed by the school teacher in Sub-study 2: *"The station with the film about Asia was the fun one. The film was very pedagogical. The station about Oceania was the hardest. The problem was too intricate. Though, the puzzle concerning Nelson Mandela was quite easy to solve".*

Hence, it could be interpreted as easier to construct problems/challenges in which the school students really have to collaborate to find the right answer however it is a quite complex process to formulate questions/problems that are spot on as concerns school student age and knowledge level. When comparing all the sub-studies as to the complexity of problems/challenges presented for the school students and in which ways they had to process knowledge and use problem-solving skills, Sub-studies 2 and 3 differed from Sub-studies 1 and 4 to some extent. Sub-studies 1 and 4 had more separated stations with problems to solve at each station and no connection between them. During the design process, the university students in Sub-study 4 divided the responsibility for the stations between them and developed their own station by formulating the problem/challenge. In Sub-studies 2 and 3 the university students instead collaborated more on developing the stations together. For example, in Sub-study 3 during the field test, the school students had to use knowledge gained at one station (what they learned) to solve the problem at another station. The university student group in Sub-study 3 were more focused on designing their concept to achieve deeper and meaningful learning. Not merely presenting a problem/challenge with a straight answer or facts to establish. They also used the Octalysis framework more frequently in the concept construction phase than, for example, the university students in Sub-study 4 who did not use the framework at all, even if it was presented to them in the beginning as a support for designing a gamification activity. This was confirmed by the teachers in Sub-study 4 who thought the university students' gamification activity was fun and motivating for the students but could only be effective as a repetition of knowledge. However, they did not see any benefit from using this specific gamification activity as a pure learning module to gain new knowledge and access deeper learning. In contrast, the teacher in Sub-study 3, when discussing the complexity of the problems/challenges the university students had created said: *"Well, if they [the school students] are given tasks where they are able to reason and argue with each other on an assignment, their knowledge should stay around better and they should get a better understanding and the knowledge they gained would be deeper."*

7 Discussion and Conclusions

The integration of emergent technologies and emergent teaching practices such as gamification teaching activities in K-12 education is thus a quite complex process (see also for example [12][21]) and teachers appear to have a low level of preparedness as concerning the design of what is perceived to be, to them, new teaching practices. In addition, they do not appear ready for the use of new emergent technologies in teaching designs. Consequently, competence development in this area is necessary. Especially, as that this type of teaching differs from traditional teaching methods [9]. Mårell-Olsson [21] found in her study that teachers' readiness level as concerns designing emergent teaching practices such as gamification activities in a school context is low and that there is a considerable need for competence development if they are to be ready to implement this in a school context. The problems or the challenges the teachers perceived in the study primarily concerned creating what may be called *a pedagogical balance* between what school students experience as fun elements and a knowledge level suitable for the school student preunderstanding of the topic. More specifically, the pedagogical balance concerns the learning process in which students are acquiring knowledge while they at the same time having fun and learning specific content. This could be interpreted as teachers lacking pedagogical knowledge [11] concerning the use of gamification as a teaching strategy. In addition, teachers also lack, to some extent, the technological knowledge [11] concerning the use of emergent technologies in teaching. The most challenging part, according to the teachers in the study mentioned above [21], is the actual design process and the tools to use in this process (i.e. brainstorming tools and different design steps to promote motives and goals using the teaching designs). This could be compared to what Koeler et al. [11] describe as pedagogical knowledge.

The university students in this study, on the other hand, had access to tools to use for the design process (from idea generating to the actual finished product) but, they struggled with this to some extent anyway, even if they had previous experience from earlier courses that included theories about design processes. This concerned more gamification as a new concept for them and what the concept included. According to the TPACK Model [11] this could be interpreted as lack of pedagogical and content knowledge at the beginning of the project. However, as the project progressed, the university students gained knowledge of gamification as a teaching strategy. This could be interpreted as that they overcame their lack of knowledge in this domain during the course of the project. In contrast to the teachers in Mårell-Olsson's study [21], the university students in this study had to struggle more with their understanding of the knowledge level the content, questions or constructed problems/challenges in the gamification designs, so they would not be perceived as too easy or too hard for the school students to solve. It was more difficult to overcome this perspective in the pedagogical knowledge domain area, even if the university students received feedback and were supervised by the teachers along the way. On the other hand, the university students had enough technological knowledge [11] about emergent technologies and their added value since they also created their own applications to use in their design. When integrating emergent technology into the teaching design, the technological knowledge (Koehler et al., 2013) concerns being able to decide which technology should be used in which problem/challenge and in turn what the added value is in the use of the specific technology chosen. A combination of all these different knowledge domains [11] is necessary and, in addition, must be combined and valued in the design process at every single step when designing for this type of gamification teaching activities using emergent technologies. Koehler et al. [11] describe these skills as forward-looking, creativeness and an open-minded seeking of technology use to advance school student learning and understanding.

A teacher thus must to have a feeling for the right pedagogical balance and enough knowledge on how to combine the different knowledge domains in the design process. This is a complex process, but includes very important skills for a teacher to have if the result is going to be a well-designed gamification teaching activity using emergent technologies to enhance student knowledge acquisition and learning processes. Otherwise, there is a risk that a gamification teaching design could be perceived as merely fun and motivating but not as addressing meaningful learning [28]. The Mårell-Olsson study [21] illustrates the fact that teachers in school are in considerable need of competence development since they lack knowledge of the gaming culture. Teachers do not generally game themselves and they also, to some extent, lack knowledge of school student habits around gaming. In addition, they lack knowledge about the concept of how gamification designs (i.e. using game dynamics and game mechanics in the teaching design) might foster student motivation and commitment to schoolwork.

Consequently, school teachers face challenges that concern how to think and act regarding re-designing traditional instructional teaching towards more learning expedition design [19] and, in addition, combining the different knowledge domains [11] in their teaching designs. Using engineering university students as co-creators when designing gamification activities for K-12 education purposes could be one way of solving this problem. This designed-based research shows that the use of the university students as co-creators makes it possible to access their technological knowledge and acquired pedagogical knowledge. This is then combined with school teacher content and pedagogical knowledge about the previous knowledge levels of the students. This type of co-creation could maximize the effect of finding the right pedagogical balance between what school students perceive as fun without sacrificing focus on their knowledge acquisition and learning process in order to achieve meaningful learning using emergent technologies [28]. The complexity of the design process, the puzzle of combining the different knowledge domains [11], could be regarded as the necessity of being aware of practical motives and goals on several levels [38]. In addition, there is also a need for knowhow regarding how to achieve both the motives and goals for the intended gamification activity as well as the use of the emergent technologies and the added value they afford by controlling operation of the actions [38]. However, individuals are different and possess different knowledge and skills and this must be regarded in the co-creation process when several individuals are included. This concerns how well they adapt to the situation in terms of their ability to become aware of their place within an activity system (the design processes in this study). In addition, the same also applies to the individual to become aware of his/her own self within such an activity system and what he/she can contribute within the co-creation design process [38]. However, whether using university students as co-creators for gamification teaching activities for K-12 education would be efficient and if this could be a way of influencing student motivation and commitment to schoolwork is a research area that is empirically unexplored. This study illuminates that the design process for gamification teaching design using emergent technologies is a complex process. Collaboration with a university and identifying university students who are willing and also taking courses that fit the task of designing activities for K-12 education is not that simple to find or organize.

8 Limitations and Recommendation for Future Research

A methodological concern with this study is the selection of participants. If the study had included more participants, cases and interviews it would be possible to have obtained more extensive data and richer nuances. However, time limitations made further data collection impossible. For example, one restriction was that the university students had other mandatory assignments they had to complete during that term and they were also attending other courses. Another methodological concern is the applied thematic analysis approach [41]. Different results could have been obtained if a more theory-driven approach had been applied. However, the chosen combination of thematic analysis [41] and Activity Theory [38] and, in addition, the use of design-based research methods [37] was regarded as useful for the analysis process in order to obtain an understanding of the concept of using university students as co-creators and the complexity of gamification teaching designs using emergent technologies. The first recommendation for future research is not only to extend the number of participants but also to conduct more design-based research on how teachers could use, for example, the frameworks for gamification design principals that the university students developed in this study when teachers wish to design gamification teaching activities using emergent technologies in their own classrooms. This would broaden the understanding and perhaps add other perspectives and more opportunities to use university students as co-creators for designing gamification teaching activities using emergent technologies for K-12 education.

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