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Introduction

In this special edition of EJEL the focus is on the use of game construction tools, games and gamification in different learning contexts. The papers represented here are a selection of extended papers from the 9th European Conference on Games-based learning (ECGBL), held in Steinkjer, Norway at Nord University in October 2015.

There are lots of initiatives on the subjects with numerous interesting experiences to be shared. Learning by doing has for quite many years been looked upon as a vital factor for increased learning outcomes. Seen from learning theories on younger children, play is also (and has always been) a vital factor for increased motivation, stamina and learning outcomes.

Digital games and gamification are increasingly implemented in education. We see many success stories, but also many challenges, both in regards to the pedagogy and the technology. There is a need to bring the topic of digital games and education more into the teachers’ educations around the world and subjects focusing on enhancing the knowledge and the skills when it comes to implementing digital games as tools for learning in pedagogical contexts needs to be further developed.

We see that many digital games, made for the purpose of learning, fail to increase motivation, stamina and learning outcomes. It is therefore also important to focus on the technological properties of the digital games to see what factors are important to enhance student’s motivation and learning outcomes.

Integrating games and game development tools into educational settings is challenging and the concept challenges the entire learning environment on several aspects; The need for changes in teachers’ skills and knowledge; The need for new pedagogical ways of thinking; The need for new ways of organizing the learning activities; The need for new ways of measuring learning outcomes; The need for better game play requirements for digital games for learning; The needs for new ways of rewarding; etc.

Esjing-Duun and Skovberg from Aalborg University in Denmark look at how student behavior and interactions change when teachers use “producing” as a primary pedagogical strategy in their paper: Copycat or creative innovators? Reproduction as a Pedagogical Strategy in Schools. They emphasize the importance of understanding how students explore creativity and playfulness while producing in a learning situation. Their work is based on a research project called “Children as learning designers in a digital School (2013-2015), funded by the ministry of education in Denmark. In their research they approach creativity and playfulness as new methods for learning. They further point out the importance of skills and acknowledgement of reproducing and remixing existing materials and how playfulness is a vital predecessor for creativity to occur.

Gamifying learning activities is an interesting approach when aiming to enhance motivation, engagement, stamina and learning outcomes in education. In the paper “Climbing up the leaderboard: An empirical study of applying gamification techniques to e computer programming class”, Fotaris, Mastoras, Leinfellner and Rosunally studies the effects of gamification and how you can combine a problem-based learning approach with elements of gamification for complex and traditionally “boring” subjects. They used the “Kahoot!” Classroom Response System and Codeacademy’s interactive platform as the bases for a learning model for an entry-level Phyton programming course. Even as a relatively small scale study they found that with the group of students being put through the gamified version of the course, attendance, downloading for course material and final grades were slightly better than with the control group. The paper proved that the gamified approach was both motivating and enriching for both the students and the instructors.
A more recent approach to the field of education is the approach of Game Construction as the main activity for the learning activity. Jensen, Droumeva and Fraser explores “Game Construction Pedagogy” as a vehicle for enhancing computational literacy in their paper “Exploring Media Literacy and Computational Thinking: A game maker curriculum study”. Their main focus in not on playing games for learning, but on constructing games as a means for learning. Founding their ideas on Seymour Papert’s constructionist learning model the authors have tested the use of the game construction software Game Maker in a pedagogical setting with 6th grade students, with the aim for increasing STEM related knowledge and skills amongst the target group. With respect to gender they find differences between boys and girls in attitudes toward computers and programming and that boys demonstrate a slightly higher confidence and performance. The paper further theorizes game construction as an educational tool, connecting it to wider STEM-oriented learning objectives in ways that can benefit both girls and boys in the classroom.

When integrating digital games into the learning context the teacher role changes, which again effects the need for new / different knowledge and pedagogical skills. In the paper “Educational games in practice: The challenges involved in conducting a game-based curriculum”, Marklund and Taylor focus on the teacher’s role and qualifications for implementing educational games. Based on two case studies, collaborating with K-12 teachers to use MinecraftEdu as a classroom activity for a period of 5 months, the authors identified a variety of roles that the teacher needs to take on if they are to make games a central part of a school curriculum. Taking on these roles the skills of the teachers are challenged, involving technological know-how, gaming literacy, subject matter expertise and a strong pedagogical foundation. They also outline the need for a better understanding of the context in which the games are to be used.

The paper “E-learning Sudan, Formal learning for Out-of-School children” by Stubbe et.al. is looking deeper into the use of digital games for children in Sudan that do not have to opportunity to go to school (showing that 2.3 million children in Sudan are not in school). The project designed a Math game where instruction and feedback were incorporated into the game itself. The game was tested during two Pilots, with groups of pupils with and without the assistance of teachers. The E-learning Sudan (ELS) game proved to increase mathematics knowledge acquisition in numeracy and adding significantly, and it maintained student motivation to learn. The authors also found that children in the experimental group learned more than children who received no education at all. In addition, the paper gives good insights into the many challenges of doing a project like this in Sudan.

The papers presented in this version of EJEL all focus on important topics for successful integration of digital games, gamification and game construction tools in education. While more research is still needed, these papers all gives deeper insight to the topic and many of the future challenges. Enjoy the reading of this issue.
Copycat or Creative Innovator? Reproduction as a Pedagogical Strategy in Schools

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Abstract: This article explores how student behaviour and interactions change when teachers use ‘producing’ as a primary pedagogical strategy (Papert, 1980; Ejsing-Duun and Karoff, 2014). Based on observed student and teacher actions and responses, as well as students’ production, this paper emphasizes the importance of understanding how students explore creativity and playfulness while producing in learning situations. This paper is based on a large research project called ‘Children as Learning Designers in a Digital School (2013–2015)’, funded by Denmark’s Ministry of Education, which included fieldwork in five Danish public schools, involved about 500 students, and comprised six interventions in the first, second, fifth, sixth, and tenth grades. The project’s empirical data consist of observations, participatory observation, and productions students created during the interventions. This paper presents an analysis of how students were creative and playful while producing learning material as games during three of the project’s interventions. The study is based on a specific understanding of the creativity with a point of departure (Boden, 2004; Tanggaard and Wegener, 2015) and playfulness (Karoff, 2013) that occur in learning situations. We approach creativity and playfulness as new methods of learning, through six areas of change that inform ‘[...]how today’s kids play and learn, and, more generally, how they see themselves, relate to others, dwell in place, and treat things’ (Ackermann, 2013: 119). This paper investigates how educators handle children’s productive processes in a school setting and how teachers can conceptualize and nurture play and creativity as drivers for learning. In this context, the importance of skills and acknowledgement of reproducing and remixing existing materials is discussed. We further argue that playfulness is necessary for creativity to occur. From this point of view, it is possible to understand how learning activities can support creativity—an essential twenty-first century skill (Levinsen and Sørensen, 2015).

Keywords: (re-)production, creativity, innovation, playing, learning, games

1 Introduction

This paper addresses the question of how creativity and playfulness inform and qualify learning processes in schools. More specifically, it explores how student behaviour and interactions move towards creativity and playfulness when teachers introduce ‘production’ with digital tools as a primary pedagogical strategy (Papert, 1980; Ejsing-Duun and Karoff, 2014). Based on observed student and teacher actions and responses, as well as on students’ production, the paper’s goal is to emphasize the importance of understanding how students can explore playfully and be creative while producing in learning situations and how teachers can facilitate this process.

Production as a pedagogical strategy shows good learning results. Previous research has demonstrated how children learn through production (Papert, 1980; Sørensen & Levinsen, 2014; 2015). Papert focuses on how teachers can frame production as a way to work towards learning objectives by creating an environment that allows children to explore a subject. Cebeci and Tekdal (2006) have also shown how production has a positive learning potential when young people create podcasts about relevant academic subjects. Students need to be actively engaged in creating products that are personally meaningful to themselves and others. Kress (2010) points out that the abstract aspects of the curriculum become tangible through different materials. When producing, students translate abstract aspects into tangible and interactive dynamics in environments that, if carefully framed, allow students to explore the subject matter through meaningful productions. Producing is not a new idea in education. However, according to Kafai (2006: 36), producing games has untapped potential: ‘Far fewer people have sought to turn the tables: by making games for learning instead of playing games for learning’.

Our contribution to this approach is to analyse how Danish children work creatively and playfully with digital production in math, physics, physical education (PE), and Danish. The term ‘game’ is applied here in its broadest form, which includes both games bound by rules (ludus) and unstructured games (paideia). Ludus is a...
term linked to Roger Caillois (2001), who wrote the book Les jeux et les homes (in English: Man, Play, and Games), published in 1958. He distinguishes between paideia and ludus, claiming that play exists in different forms that can be placed along a continuum on which one extreme is paideia (unstructured and spontaneous) and the other ludus (based on explicit rules). When producing games, the children can tap into an area that they are experts in, and use that knowledge to create something new (Ejsing-Duun, 2011; Karoff, Ejsing-Duun and Hanghøj, 2012).

Creativity (Boden, 2004; Tanggaard and Wegener, 2015) and playfulness (Karoff, 2013) occurred in this study’s observed learning situations. By introducing six dimensions that inform how children play, learn, and create, based on Ackermann’s (2013, 2014) work, we sought to investigate how students use materials and design processes to explore. As a result, this paper’s main contribution is to show how students can be creative in various ways when extracting knowledge from their game experiences and information on game genres in schools. Furthermore, we seek to challenge the common understanding of creativity as something totally new created out of nothing (jf. Tanggaard and Wegener, 2015; Mason, 2003). Instead, we urge teachers to frame and embrace the potentially constructive disruptions and necessary copying that allows children to be productive and, sometimes, even creative.

The next section introduces the research context. Section three presents the theoretical points of departure. Section four analyses three learning situations that arose during our empirical research. Section five discusses the concepts of creativity and playfulness in the context of learning.

2 Research context

This paper is based on a large research project called ‘Children as Learning Designers in a Digital School (2013–2015)’, funded by Denmark’s Ministry of Education. This empirical research consists of fieldwork in five Danish public schools, involving about 500 students and 30 teachers, and it included six interventions in the first, second, fifth, sixth, and tenth grades. The schools were chosen from a pool of candidates to guarantee geographical and socioeconomic dispersion (Levinsen et al., 2014). The project explores the area of students’ production and involvement, and, more specifically: 1) how students’ digital production affects learning processes and the quality of learning results regarding subjects and trans-disciplines and 2) how information and communications technologies that allow students to act as designers of their own learning practice in terms of form, framing, and content affect their learning, engagement, and motivation.

Due to the project’s complex nature, a mixed methods approach was used. In their research, Johnson and Onwuegbuzie (2004) sought to overcome incompatible findings within a complex field. This, in turn, has led us to follow a strategy linking fieldwork inspired by ethnography and design-based research that emphasizes experiments and collaboration with practitioners (for a further elaboration of this methodology in Levinsen et al., 2014, see also Magnussen and Sørensen, 2010, and Cobb et al., 2003). As Johnson and Onwuegbuzie (2004: 16) suggest, the ‘[b]ottom line is that research approaches should be mixed in ways that offer the best opportunities for answering important research questions’. The present study’s empirical data consist of observations, participatory observation, and productions created by students during the research project. In this paper, we focus on three significant situations to illustrate a tendency in our observations, which are presented in the following three subsections.

2.1 “Are you fooling around?”

This example is taken from a mathematics intervention with children in the first grade (approximately eight years old). The children were introduced to the computer program Geogebra. The assignment was to create a shape using this mathematical tool. Afterward, the game called for the children to exchange shapes with their classmates and imitate another shape.

Oliver is a boy who often goes his own way. At the beginning of the intervention, he refused to use Geogebra and, instead, drew his shapes in Paint (a Microsoft program). During the second week, he used both programs, still preferring Paint and often running both programs at the same time. However, he did draw a mouse in Geogebra, using shapes of circles in different sizes. The teacher told him to use Geogebra for his assignment, and, thereafter, he closed Paint or immediately switched to Geogebra whenever the teacher came near. In the end, as other students evaluated their assignment, he changed his mouse picture, drawing on top of what he had already made, and, instead of evaluating it, redesigned the figure. Contrary to his classmates, who all did
almost the same green star with blue corners, Oliver apparently needed to continuously play around with the shapes and the tool’s possibilities. The only way to do that was to avoid attracting the teacher’s attention and do something different than the others.

2.2 “Did you make this yourself?”

This example is taken from a mathematics intervention in which children in the fifth grade (approximately 11 years old) were instructed to program games using iPads and the software application (app) Hopscotch. The children were extremely engaged in creating good games, and they worked intensely on their products. They asked for extra lessons on mathematical subjects relevant to their games, including complex areas such as algebra and exponential growth. They also assessed each other’s products throughout the project (the example is also discussed in: Misfeldt and Ejsing-Duun, 2015).

Simon is a student for whom math is hard. From the beginning, he failed to complete the tutorial—a sequence of tasks designed by the teacher that introduced students to programming with Hopscotch. However, he was highly engaged in the process of making a game. In the morning on the project’s third day, he found the teacher before class had started to show her his progress. She looked at the game that he had made and asked him whether he had made it himself. He replied that he indeed had developed it himself. She inquired about several features of the game, and he had difficulty explaining how they had been made. He continued to work on the game throughout the next period. As he uploaded his finished game, an icon indicated that he had retrieved a coded game from the Hopscotch community and remixed it.

In the end, as other students presented their games, Simon followed their information with interest and then presented his own game. After he had received feedback on the game, he continued tweaking it in terms of speed, points awarded, and so on. Once the project was finished, the teacher emphasized Simon’s motivation as a particular success and benefit. He was captivated by the process, and he kept working with the subject matter, without even asking for much help. She pointed out that he has academic difficulties and, normally, has a hard time following lessons and presenting anything to the class. Without doubt, Simon felt ownership—and was proud—of his game. We cannot conclude whether his learning outcome was significant, as this was not assessed, but Simon did learn that math could be interesting for him and a meaningful way for producing games.

2.3 “I would like to change it a bit, because it needs to work”

This example is taken from a trans-disciplinary intervention between PE and Danish with children in the first grade (approximately eight years old). The children were introduced to seven different traditional games in PE, primarily hiding and catching games, both working in teams and working individually. The assignment was to create a new game and a multimodal instruction text of how to play the game. The game was supposed to be played by other students using the instructions.

Nadja, Maya and Adam were working as a team on a game that combined elements from hiding games with elements from catching games, both of which they had tried during PE. The reassembled existing knowledge came both from PE and from the children’s wide repertoire of different games that they spend time on outside school. They designed a game where all but one of the participants have to hide while the finder/catcher counts down, then the finder/catcher must find each participant and catch them—if they fail to catch someone, that person can hide again.

The teacher encouraged the children to play their game several times to make sure it worked well. The teacher also tried each game, and offered constructive feedback that led to the students revising their games and instructions. As a final, all the children tried out the different games. The team that came up with the game would remain inside while the children trying the game were outside. The designers could watch how other teams played their game—and thus see how well they understood the instructions—using FaceTime. With no way of talking to the students trying the game out, the designers were only an audience for the game they invented. They experienced how their game worked for others, and they wanted to change parts that did not work out as they thought it would. The teacher encouraged them to change any parts that did not work. By following the iterative process of creating the game—trying it out, re-creating the game, having others try it out, and lastly re-creating the game again after seeing any errors and possibilities for improvement—the teacher and the students shared a meaningful and educational experience.
3 Creativity

To many researchers, creativity is still first and foremost associated with what is new and meaningful. Mason (2003: 7) states: ‘To create is to act in the world, or on the world in a new and significant way’. In that perspective, repeating or copying something is not considered creative just as routine activities, such as practicing in order to master a specific task, are not creative. However, recent research has a critical perspective regarding this ‘obsession with novelty in public organisations and public rhetoric’ (Tanggaard and Wegener, 2015: 14). That is the case for Boden (2004), Ackermann (2013) and Tanggaard and Wegener (2015). To them, nothing comes out of nothing, and combining or re-mixing existing materials with new situations is considered an important aspect of creativity. Tanggaard and Wegener (2015: 1) specifically argue against the ‘[…]excessive enthusiasm towards the novelty aspects of creativity and innovation, which overshadow the potential of old ideas and past experience as drivers of change’.

Boden (2004) is preoccupied with understanding the phenomenon of human creativity and how computers can help us understand it, as well as using the understanding of creativity to model computers. Understanding creativity from this perspective is relevant as digital media is used as a driver for production in all of the three examples. Tanggaard and Wegener (2015) are interested in re-creation and re-creativity as part of innovation and how to translate this perspective into a pedagogy that teaches people to work in a creative fashion, which is relevant to the focus of this article as we want to suggest how teachers can nurture creativity in school. Ackermann (2013, 2014) addresses the way children play and learn through interactions with others and with things, which is included here as we also want to understand how children approach creativity and production.

3.1 Nurturing Creativity

Tanggaard and Wegener (2015) underline the importance of focusing on imitation and already existing knowledge when creating the best possibilities for creativity to happen. Their paper highlights creativity as a result of a reinvention or resampling of existing material and acknowledges already existing practices and ideas as an important point of departure. Tanggaard and Wegener (2015: 15) argue: ‘[…]if innovation is in reality built on re-creation as suggested in this paper, schools could become a kind of museum innovation hubs—simultaneous a place for the old and the new and its fusion’. In order to support students’ creativity, they need to experience ‘[…]educational structures and practices that encourage access to existing and “old” knowledge seen as potential bricks for future re-creation, while also allowing for a greater personalisation and autonomy of learning’ (Tanggaard and Wegener, 2015: 14). This means that students are not taught a set curriculum which represents the world as it is but are instead allowed to form new ideas about the world. This is nurtured through possibility thinking that challenges students and teachers to pose ‘what if?’ questions. These questions ‘[…]can only be formulated and answered by adopting new positions towards the problem at hand, by noticing not only how things “are” but how they “can” or “should be”’ (Tanggaard and Wegener, 2015: 14). To encourage creativity in schools, it is necessary to give learners the time they need to ‘dig deep’ into a subject through research, experimentation, and revision (Brinkmann and Tanggaard, 2009). Teachers must emphasize not only the product, but the process as well. The production process must happen along with ‘[…]perception and reflection by looking for models to emulate, and finding links between those models and one’s own work’ (Brinkmann and Tanggaard, 2009: 252). Throughout this process, feedback from peers and teachers is essential for learners to reflect upon their findings.

Boden (2004: 28) agrees that ideas grow out of what is: ‘Insights do not come from gods—and they do not come from nowhere, either. Flashes of insight need prior thought-processes to explain them’. In other words, what is new builds upon what lies before. In order to nurture creativity the teacher needs to be able to recognize it. Boden has described creativity as having three forms. These three forms relate to the subject matter—in Boden’s words, the ‘conceptual space’—in three different ways.

The first form is combinatorial creativity, which exploits shared conceptual structures to create analogies or metaphors. As an example, Boden mentions how a journalist might compare a politician with an animal, creating a conceptual pathway between the two. The process, thus, is guided by associative forms. Similarly, Tanggaard and Wegener (2015) point out that scanning a different (foreign) domain than the conceptual space one is working with for old and well-established ideas and combining these ideas with the new domains and practices, i.e., the conceptual space, is a great opportunity for creating something new. In game production,
game knowledge is used as a metaphor to highlight dynamics in the conceptual space, but also knowledge about previous game designs and experiences is applied.

The second form, explorative creativity, relies on culturally accepted styles of thinking (i.e., artistic genres). This conceptual space is restrained by a set of generative rules and is employed when being creative in an explorative manner. When producing games, players need to explore the rules’ structure throughout the game production in order for the game to be playable. According to Tanggaard and Wegener (2015: 2), ‘[…]much inspiration to innovate among practitioners involving creative actions can come from what is “old” and that a practical as well as a theoretical shift to re-creation is timely and relevant’. This implies exploring the existing thinking used to address the domain that is being innovated and perhaps framing it differently.

The last kind of creativity implies that this conceptual space is altered altogether. This is what Boden calls transformative creativity. As she writes:

\[ \text{A given style of thinking, no less than a road system, can render certain thoughts impossible— which is to say unthinkable. The difference, as remarked above, is that thinking styles can be changed—sometimes, in a twinkling of an eye (Boden, 2004: 6).} \]

To combine, explore, and transform are all essential ways in which creativity can happen, according to Boden. Indeed, Ackermann (2013) has seen these modes of practice among children growing up in the digital age. Ackermann suggests six areas of change in how children today apply old ideas to new situations.

### 3.2 Creative ways of being productive

In her paper ‘Growing up in the Digital Age: Areas of Change’, Ackermann (2013) identifies six areas of change that appear to inform how kids currently play and learn and, more generally, how they treat things, see themselves, dwell in places, and relate to others. In our research, we found these areas inspiring as a framework for understanding production and creativity, not only as something children do but also as the ways in which they do it. In the following discussion, we present Ackermann’s six areas.

According to Ackermann, **sharism** is the first dimension characterizing today’s children. They share even before they think of the finished state of their productions, not keeping things to themselves. **Fluid selves** is another aspect, where children explore different versions of themselves through multiple digital, virtual, and physical realms. **Crossing borders** is the third dimension. Ackermann points out that children move between worlds and urge others to cross both cultural and geographical borders. The fourth area of contemporary children’s renewed approach to the world is the **literacy** dimension, in which children find new ways of expressing their experiences. They blend text, sounds, and images, and often borrow from those who inspire them. They invent new genres of writing by remixing, repurposing, and reconfiguring. As the fifth area, Ackermann mentions a **culture of gaming** or ‘simulating’, which she uses to challenge the myth of gaming as escaping from reality. She states:

\[ \text{Games, like play, are more like a vacation. They offer a voie royale into the realm of “altered possibilities” which allow returning to “real life” better prepared, refreshed, stronger . . . Kids use fantasy not to get out of but into the world. They make up fictions, or dramatize everyday events, in order to de-dramatize the sometimes hard-to-handle reality. Intelligenc itself, to Piaget, is about establishing a dialog between what is and what could be! (Ackermann, 2013: 125).} \]

Simulating indicates a creation of an alternative world that is true and believable in its own right, in contrast to simulating, which implies pure reproduction. Ackermann’s point is that children today use the digital tools that they are presented with, or already have, to try out playful exploration in ways rarely possible with pre-digital tools. These children expect immediate feedback and use these tools to ‘simulate’ various ways of doing.

**Tinkering**, in Ackermann’s (2013: 126) perception, is exploring and extending the understanding of technology or situations through using and ‘making things “do things”’ and this is her last characteristic way children today create—as **bricoleurs**, **makers**, **hackers**, and **hobbyists**. By trying things out, mixing things, and mending things together, they explore the possibilities of the world through what they create together. Through an iterative process of tweaking things, they empower their creations. The core point here is that they act before they think—or rather, they think while acting.
3.3 Playfulness in creative processes

Playfulness, in our understanding, is related to a way of being, in which goals and usefulness are not always at the centre of activities (Ejsing-Duun, 2011; Karoff, 2013). Ackermann (2014: 1) addresses being playful in creative processes as a necessary aspect since “[...]coming at things obliquely”—through suspension of disbelief (pretence), artful détournement (displacements), and playful exaggeration (looking at things from unusual angles)—allows [one] to break loose from the habitual’. To reach the stage in which one combines aspects normally not associated, explores the unknown and the known in fresh ways, or even transforms the area of interest, one needs to break habits and, sometimes, even perform what appear to be useless activities. Transgressing boundaries in playfulness is a driver for practices of change—and thus for creativity. These processes should not be tamed because, as Ackermann suggests:

[B]eyond our rational mind’s temptation to plan ahead and to stick to the plan (unless proven wrong or irrevocably cornered), and the blind maker’s insight-less errings, the playful wanderer enchants us through his own wondrous musings. S/he knows to look at things obliquely, cares to see what others don’t, and uses his/her intelligent hand—and connection to the materials—to bring forth the unexpected (Ackermann, 2014: 8).

This approach means that creators need to relate to the conceptual space within their interests without following a plan towards predefined objectives. However, as suggested by the above research, changing perspectives, experimentation and revisions are core activities that should be encouraged throughout the process, as it is important that learners gain feedback—and feed-forward—in order to reflect upon the productions (Levinsen and Sørensen, 2015).

4 Analysis

Based on our study, we present the following important findings. First, an important part of creativity is exploring and trying things out in a playful—sometimes even foolish—way, without any specific goal. Second, ‘copying’ material and reworking premade material are important aspects of creative production that can lead to learning. Third, teachers need to engage in and appreciate the process of building upon existing material by providing and encouraging feedback and challenging students to ‘dig deep’.

4.1 Copycat or innovator?

Creative exploration is frequently based on a close imitation of something children already know extremely well, building upon existing knowledge, or something already produced, which is often mistaken for copying. When Simon made a game with the programming app Hopscotch, he downloaded an existing game and tweaked the codes and graphics—he hacked the game as a bricoleur and managed to navigate the game’s digital layers. This is what Ackermann (2013) coins as taking literacy beyond print, i.e., extending his ability to express himself to new media. He took the initiative to present his work to his teacher, sharing it without paying attention to whether it was finished. While hacking the game, he was simulating a creation of an alternative world; rather than creating a faithful reproduction of the original, he was adapting an existing game to his own purpose (Ackermann, 2013).

Being a student who is challenged by math, Simon would probably have been lost in the rather complex process of learning to program and invent a game from scratch, had the teacher insisted that this was required. However, Simon was engaged in changing variables and observing how values affect speed, positions, and geometrical shapes—all of which were matters relevant to the subject at hand, the conceptual space. Simon might not be an ‘innovator’, since he did not combine areas of knowledge or transform the conceptual space, but he worked creatively, exploring the field of interest and rehearsing and applying his knowledge of math. He explored how he could express himself through coding (literacies beyond print) as he reconfigured the game code that he had ‘borrowed’, and he hacked the game through an iterative process. He also sought the opportunity to explore the area even further as he shared it with the teacher, without thinking about what stage his work had reached.

Simon is not the only student who took a premade game as the point of departure for programming with Hopscotch. The data contain more examples of students who tweaked previously made games and applied pre-programmed blocks to their game. In this way, Hopscotch enables differentiation. However, this method was made more challenging by the teacher, who prompted the students to present their games to the class. In the presentations, she had the entire class explain the features of each game, then she had each student who
had designed a game describe how he or she had actually made it. In addition, the teacher challenged the class to find ways to improve their games and to explain their methods. Through this process, the teacher kept the focus on the conceptual space the students were exploring through their design processes—namely, algebra, variables, and algorithms—by facilitating discussions of their productions that related their work to the learning goals (Ejsing-Duun, Hanghøj and Karoff, 2013). This was still relevant to the children as they wanted to learn this in order to improve their games.

4.2 Destructive or constructively disruptive?

In Oliver’s class, imitation and copying seemed the main way to produce shapes, but Oliver did something else. While Oliver was trying the Geogebra program without a specific goal, he drew a funny mouse, came up with a story, and telling it to a friend, all within 10 minutes. By analysing the situation using the concepts of sharism and tinkering (Ackermann, 2013), an interesting observation is the ways ‘messing around’ with the digital tool facilitates creative and playful behaviour (Ito et al., 2009). This is an excerpt from the field notes:

Oliver opens Geogebra. His teacher has given him an assignment. He must draw a figure. Afterwards, he must give his figure assignment to a classmate. His classmate, then, must be able to make the same figure. Oliver makes a circle, he draws two lines across, some ears of two other circles, and, now, he has a mouse. He moves the lines within the mouse and talks with a mousy voice. Oliver laughs, he turns to Ida-Marie, the girl next to him. ‘Look,’ he says. He modifies his voice into a mouse voice, as he moves the two lines up and down, and it looks like a talking mouse. Ida-Marie is listening to the story, and Oliver says that his mouse is moving toward a dangerous mission. Ida-Marie laughs. Oliver continues to move the lines faster and faster, and the mouse eventually shouts very loudly (translated from Danish in field notes)

Oliver did not understand the program or digital tool extremely well; as mentioned previously, he preferred Paint. However, in this situation, he ‘messed around’ with the features, trying things out and drawing a mouse using circle shapes. He was not at all tuned into the assignment’s goal, but, instead, his practices were explorative, resulting in a story told to his friend. In other words, they were playful as he was exaggerating the use of the tool (Ackermann, 2014). According to Ackermann’s (2013) concept of ‘tinkering’, Oliver let the tool guide him, playing with features and possibilities as he explored the program. Neither the story nor the drawing was planned beforehand. Instead, Oliver was developing both while creating them, and, while he was doing this, he shared them. As Ackermann points out in her definition of sharism, sharing is the centre of accomplishments, and Ida-Marie became Oliver’s audience, as her laughs made the lines move even faster.

Fooling around with digital tools is a well-established practice in classes for introducing something new to students’ production processes. The data include several examples of students tinkering and fooling around while thinking. Teachers’ ideas of learning practices are challenged by this type of creativity, primarily because the activity’s goal is blurred. As Karoff (2013) mentions, this is quite distinctive to playfulness, and, using Ackermann’s (2014) idea of looking at things obliquely, Oliver’s practices seem to be driven by this process. He brought something unexpected to life, in connection to the material with which he was working. By introducing his classmate Ida-Marie to his unexpected exploration, he underlined the importance of sharing creative unexpectedness with others in order for the process to remain meaningful. However, in this specific case, the teacher was constantly keeping an eye on him, making sure that he did what he was supposed to do. She saw his fooling around as being destructive and not heading towards her planned goal.

4.3 Possibilities of iterations

By analysing the third situation using the concepts of ‘old ideas influence’ described by Tanggaard and Wegener (2015), exploration and combinatorial creativity described by Boden (2004), and tinkering described by Ackermann (2013), we want to show how an iterative process of producing games can help ensure that children’s creativity is understood and nurtured by the teachers, not undermined.

In the beginning of the intervention, the children were introduced to different games as inspiration for them to make their own games; thus, previous knowledge and models were valued in the setup. Maya and Adam explained their invention (excerpt from the field notes):

We did a game called ‘Thunder Hiding’, Maya tells me. Okay, I say, can you tell me about the game. Yes, Maya says. One person is the ‘catcher’, and while that person is counting to ten
everybody has to hide. And then the ‘catcher’ has to find them, and after finding them ‘catch’ them. Adam continues telling me that you have to catch the person you have found otherwise the person is allowed to hide again.

This game ‘Thunder Hiding’ included game mechanics from both known hiding games and catching games. By combining these mechanics, the children have created a new type of game. Their knowledge of games, which in Tanggaard and Wegener’s (2015) perspective are old ideas, becomes the material for new ways of playing. The material is blended in ways different from the games they were introduced to, and this blending can be seen as an example of Ackermann’s (2013) concept of tinkering. While tinkering, the children practice playing the game in order to develop it. They explored different versions of the game to find the one that was most playable. In that sense, Ackermann’s tinkering and Boden’s exploration are closely related: the children use material to explore.

The game was not the only product of this learning process. The students also had to write an instruction manual explaining how the game is played. This gave the teacher the chance to focus on the students’ competency with Danish through the composition of pictures and instructional text, as well as spelling and writing. The students also read aloud to each other, the teacher, and to the second author of this article during the process to ensure that they included all of the instructions for the game in the manual. In that sense, creating the manual was both meaningful to the teacher and the students.

In this case, the teacher supported the blending of old ideas, the exploration of ways in which the games could work, and the children’s tinkering around to design a good game. The teacher was directly involved in trying the games out and was not only focused on evaluating the end product. She continuously invited the children to improve the game through trying it out again, and her evaluation became a feed-forward process involved in all versions of the games. In that sense, the teacher is initiating what Brinkmann and Tanggaard have described as possibility thinking, that is, constantly encouraging the students to formulate new positions towards the problem at hand, by noticing not how things are, but how they could be in the future through the question of ‘does it work the way you want it to work?’ (Brinkmann and Tanggaard, 2010). These two aspects of teacher involvement, involvement directly at possibility thinking and focus on all of the versions of the game, were absolutely crucial to the learning results of the process. These two aspects allow the teacher to understand the creative process of the children and support the development of the games in a productive way. In that sense, it is reasonable to say that introducing the iterative process to the learning situation makes it possible for the children to explore all aspects of creativity, and also lets the teacher understand and support the process of creativity in a productive way for the learning results. The students had the time to ‘dig deep’ through research, experimentation, and revision (Brinkmann and Tanggaard, 2009).

At the end of the intervention, the teacher facilitated a process of reflection upon the instruction manual to emulate the different models of the process. This allowed the students to find links between others’ methods of accomplishing the task, as well as between the instruction manual and the actual game play. This final conversation also gave the students the chance to reflect upon their process in relation to those different perspectives (see Brinkmann and Tanggaard, 2009).

5 Discussion

In our study of several schools and teachers, a recurring conception was that children often are not very creative, which resonates with the exhaustive enthusiasm about novelty. As Tanggaard and Wegener point out: ‘[...]It is often emphasised that repeating or copying something is not creative, that speaking from memory is not creative, and furthermore, that routine activities such as walking home from work or drinking coffee are not creative’ (Tanggaard and Wegener, 2015:4). In our study, many teachers saw creativity as a way of finding new and smart ways to solve specific problems related to educational objectives. They seemed to evaluate creativity as inventing something ‘new’ and previously unseen that made a difference. This evaluation and its related feedback favour the product over the process.

Some teachers expressed the worry that if they showed students an example of a premade product, the students would either simply make a variation of it, resulting in an uncreative process, or mindlessly reproduce the example and miss the potential for learning. As Ackermann writes:

A big problem among educators today is to come to grips with what they view as ‘plagiarism’: students’ tendencies to pick-up and pass-on ready-made imports that have not been ‘massaged’ long enough, or mindfully engaged (Ackermann, 2013: 125).
In order to prevent aimless copying of other people’s work or purposeless fooling around, the educators in this study made different suggestions and actual changes to innovate how they embrace and nurture productive processes. In planning interventions, some teachers considered not showing the children any examples to prompt more unique solutions. However, even in these situations, children used existing material and were inspired by each other. To prevent students from fooling around and keep students on track, another suggestion was to have them make a plan from the outset. Hence, not being goal-oriented was often understood by teachers as being unconstructive. This is in contrast to Ackermann (2014) that encourage process-oriented playfulness in creative process. These plans were seldom used throughout the processes, but served as a starting point. Yet another repeated idea was that good products require early analysis and planning before production. However, these suggestions do not support the way the children work as suggested by Ackermann (2013, 2014) and confirmed in our observations. In the third situation described above, things were somehow different. Children were shown existing games and the iterative process required that they ‘dig deep’ into the subject at hand while working on it. The different versions of the game produced during the process made the creative practices of the students clear to the teacher, and she followed along while suggesting future possibilities for the game. Also, when others followed the instructions in the game manual, their actions provided feedback to both the students and the teacher regarding how the manual worked and how the intended game was experienced. This approach resonates with both Ackermann’s (2013) and Tanggaard and Wegener’s (2015) approaches, as well as how we saw the children work. Lastly, it was clear that the students’ and the teacher’s understanding of the learning outcome corresponded (Levinsen and Sørensen, 2015).

In two of the cases, the children were allowed to draw upon their own skills as game players in order to program and design games. Furthermore, the children designed games using their knowledge of old ideas about games. However, in all three situations they needed to explore an unfamiliar subject, such as math, in order to produce their game. In this context, it is important that the children acquire needed skills to engage in the production. As an example, the math teacher who planned the Hopscotch game programming intervention began with an initial tutorial that introduced the ideas behind programming and the syntax of the programming language. She then allowed her students to find their own paths. Making an introduction of the ideas related to the conceptual space and the skills needed to experiment and produce is particularly a good idea when students are unfamiliar with the tools or with the conceptual space they are working in, as was the case in the situations analysed in this paper. The math teacher’s tutorial was designed to ensure that students were presented with the tool’s features and that students related to the conceptual space in the same way that the tutorial’s tasks related to it. The students could then fool around with the tools, trying out their features by copying and remixing content, as Simon did, to discover the tool’s limitations and possibilities. Throughout the programming process, the math teacher made an effort to encourage the children to discuss their productions in terms of mathematics but also taught them to work with formulating problems related to producing the games that made them able to address these problems. This space for reflection on the production process is crucial for learners to be able to apply the acquired knowledge to other situations (Brinkmann and Tanggaard, 2009).

We argue that learning activities with digital tools that allow playfulness can support creativity, an essential twenty-first century skill. However, allowing students to fool around and embracing copying could be unhelpful or even directly destructive. This is a challenge within school systems that are increasingly goal-oriented. Teachers need to be alert to situations that emerge, to relate them to the conceptual space whenever possible, or, even better, to teach students to do so themselves and encourage possibility thinking (Brinkmann and Tanggaard, 2009). However, learning does not need to be only linked to a specific, set curriculum that is meant to represent the knowledge in an area. Students should be able to use and challenge the old ideas they encounter throughout the process (Brinkmann and Tanggaard, 2009). When Simon ‘messed around’ with the pre-programmed game, he was learning about games, about genres, about programming, about presenting, and so on. However, if teachers want their classes to learn about algebra as a group, then they should not develop objectives but rather formulate criteria that could guide the ‘messing around’ and thus encourage exploration and combinations of materials. Furthermore, the math teacher noticed that some of the students became lost in the process when re-working games that were too complex for their level of expertise. The teacher must help keep the level of challenges and skills balanced in order for students to experience growth. It is important for the teacher to work closely with the students in the feedback process to ensure they stay within the conceptual space, i.e., the area that they are inquiring about.
The teacher’s task is to maintain the students’ focus on an examination of the conceptual space and to motivate the children to continuously explore the subject matter. The students gain a better understanding of the subject through the combination of knowledge fields or even transforming their understanding of it. They accomplish this by qualifying and refining their products. As Ackermann (2013: 121) points out, ‘Digital natives are known for their launching of half-baked ideas and creations’. For these ‘half-baked’ ideas to be qualified further, the teacher’s role is to provide time and space for continuous refinements. Thus, teachers cannot merely give students a task, send them into production mode with possible supervision, and evaluate the end products. On the contrary, working in an iterative process, in which teachers and students have time-outs during the class during which they assemble and re-evaluate students’ productions in their current stage in relation to the conceptual space and together identify criteria for the ongoing production, has proven to be highly efficient. As Sørensen and Levinsen point out:

*Ongoing evaluations with feedback and/or feed-forward can be used as short time-outs, where students and/or the teacher show and tell something that others can learn from, for example, when students have found out how to animate a graphic element (Sørensen and Levinsen, 2014: 7).*

Throughout this ongoing evaluation and production process, teachers need to remain aware of what students are combining, exploring, and transforming and how this relates to the conceptual space. The challenge is to inquire about the students’ intentions behind their ‘messing around’ and bring these into the conceptual space—or, if unrelated, dismiss them as such. Through this inquiry, teachers qualify the children’s creativity in relation to the conceptual space, and, in connection to this space, make students refine their work, not only once, but again and again.

Over time, the children themselves need to learn to think in possibilities, and to use play as a gateway to creativity. This requires that they immerse themselves, experiment and revise their work. These skills are required in the 21st century.

**References**


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Climbing Up the Leaderboard: An Empirical Study of Applying Gamification Techniques to a Computer Programming Class

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Abstract: Conventional taught learning practices often experience difficulties in keeping students motivated and engaged. Video games, however, are very successful at sustaining high levels of motivation and engagement through a set of tasks for hours without apparent loss of focus. In addition, gamers solve complex problems within a gaming environment without feeling fatigue or frustration, as they would typically do with a comparable learning task. Based on this notion, the academic community is keen on exploring methods that can deliver deep learner engagement and has shown increased interest in adopting gamification – the integration of gaming elements, mechanics, and frameworks into non-game situations and scenarios – as a means to increase student engagement and improve information retention. Its effectiveness when applied to education has been debatable though, as attempts have generally been restricted to one-dimensional approaches such as transposing a trivial reward system onto existing teaching materials and/or assessments. Nevertheless, a gamified, multi-dimensional, problem-based learning approach can yield improved results even when applied to a very complex and traditionally dry task like the teaching of computer programming, as shown in this paper. The presented quasi-experimental study used a combination of instructor feedback, real time sequence of scored quizzes, and live coding to deliver a fully interactive learning experience. More specifically, the “Kahoot!” Classroom Response System (CRS), the classroom version of the TV game show “Who Wants To Be A Millionaire?”, and Codecademy’s interactive platform formed the basis for a learning model which was applied to an entry-level Python programming course. Students were thus allowed to experience multiple interlocking methods similar to those commonly found in a top quality game experience. To assess gamification’s impact on learning, empirical data from the gamified group were compared to those from a control group who was taught through a traditional learning approach, similar to the one which had been used during previous cohorts. Despite this being a relatively small-scale study, the results and findings for a number of key metrics, including attendance, downloading of course material, and final grades, were encouraging and proved that the gamified approach was motivating and enriching for both students and instructors.

Keywords: gamification, game-based learning, learning and teaching, technology enhanced learning, virtual learning environment, classroom response system, Kahoot, assessment, higher education

1 Introduction

According to research on the dynamics of attention spans during lectures, the typical learner’s attention increases during the first ten minutes of lecture and diminishes after that point (Hartley and Davies, 1978). One way to address this issue and recapture the attention of learners is by changing the environment during a lecture, e.g., via a short break (McKeachie, 1999). This is almost the opposite of the dynamic experienced by video gamers. The latter are kept at high levels of attention, which in some cases can last for many hours (Green and Bavelier, 2006). They also have a distinct characteristic where they strive to be on the verge of what Jane McGonical (2010) describes as an “epic win”. Gamers also share common factors such as urgent optimism, social fabric, blissful productivity, and epic meaning, which in turn make them super empowered hopeful individuals (Huang and Soman, 2013). On the other hand, when confronted with complex learning, students are more likely to feel overwhelmed; there is no instant gratification or short term wins to keep them engaged and motivated. A promising way to address these counterproductive feelings is to design them out using techniques similar to ones found in successful gaming environments.

Rather than assuming that the rapid proliferation of sophisticated technologies such as smartphones, tablets, and laptop computers into every facet of society is the cause of student attention deficit (Griffin, 2014), educators should be open to new possibilities to teach and educate (Squire, 2003; de Aguilera and Mendiz, 2003). Findings of independent experiments performed in secondary and higher education settings showed that students who were subjects to learning with video games reported significant improvements in subject understanding, diligence, and motivation (Barata et al., 2013; Coller and Shernoff, 2009; Kebritchi et al., 2008; Lee et al., 2004; McClean et al., 2001; Squire et al., 2004).

In the same way that games help stimulate the production of dopamine, a chemical that is considered to play a key role in motivation, affect and learning (Wimmer et al., 2014), educational techniques which access the same methodologies could result in learning-reward cycles (Gee, 2003) by reinforcing neuronal connections and communications during learning activity (NMC Horizon Report, 2013). Additionally, unlike the one-size-fits-all lecture, these game-based techniques can be balanced to be appropriate to the learners’ skill level (Koster, 2004) in order to prevent them from becoming frustrated or bored, thus allowing them to experience “flow”, i.e., a user’s state of “optimal experience” (Barata, 2013; Chen, 2007; Csikszentmihalyi, 1990).

Gamification for learning should use game mechanics, dynamics, and frameworks to non-game processes along the following principles, which were adapted from Self-Determination Theory (Ryan and Deci, 2000):

- **Relatedness** – the universal need to interact and be connected with others;
- **Competence** – the universal need to be effective and master a problem in a given environment;
- **Autonomy** – the universal need to control one’s own life.

These elements have been shown to affect intrinsic and extrinsic motivation, which in turn can have a big impact on student engagement and motivation (Deterding et al., 2011). Intrinsic motivation (e.g., altruism, competition, cooperation, sense of belonging, love or aggression) is driven by an interest or enjoyment in the task itself and inspires people to initiate an activity for its own sake (Ryan and Deci, 2000). Students who are intrinsically motivated are more likely to engage in a task willingly, as well as work to improve their skills, which will increase their capabilities (Wigfield et al., 2004). In contrast, extrinsic motivation comes from outside the individual and refers to the performance of an activity in order to attain an outcome (e.g., earn grades, levels, points, badges, awards) or to avoid punishment (Muntean, 2011). Typical extrinsic incentives include competitions, cheering crowds, and desire to win trophies.

Individual student fatigue could be taken into account so as to determine the optimal combination of intrinsic and extrinsic motivators; this would automatically re-captivate students and provide a rewarding break without producing any detrimental effects. By introducing game mechanics into generally unpopular activities such as assessments, students would enjoy the tasks first and, in the process of completing them, they would deliver the required assessment.

However, despite the fact that gamification of education is gaining support among an increasing number of academics who recognise that effectively designed games can stimulate large gains in productivity and creativity among learners (NMC Horizon Report, 2014), opponents argue that what is lacking is concrete empirical data to support or refute these theoretical claims (Annetta et al., 2009; Barata et al., 2013). Some of the negative experiences include disappearance of collaboration among students and overstimulation of competitiveness. The balance between learning, social collaboration, creativity, and competitiveness which is apparent in mainstream commercial games seems to be hard to achieve in tools specifically designed for education (Zaha et al., 2014). As a result, gamification is often reduced into a behaviour model leveraging human need for positive reward system and instant gratification, which is applied to a traditional teacher-centred classroom.

Annetta et al. (2009) and Britain and Liber (2004) suggest that both teachers and researchers need to evaluate video games and gamification from an educational perspective, in order to determine whether they can be embedded into teaching practices. Based on this notion, the present paper aspires to make a contribution to the empirical evidence in the gamification field by designing, implementing and evaluating a gamified learning experience in a higher education setting. This research effort tries to bridge the gap between theory and practice, as well as to study the educational impact of gamification in a real educational setting. The specific research questions were:
Are students who use Codecademy and play “Who Wants To Be A Millionaire?” and “Kahoot!” more engaged in learning Python programming when compared to peers who engage in traditional class activities?

Do students who use Codecademy and play “Who Wants To Be A Millionaire?” and “Kahoot!” develop deeper understandings of Python programming when compared to peers engaged in more traditional instruction?

2 Related works

The idea of using gamification for learning is not entirely new. In the 1980s Malone (1980; 1981; 1982) did research on what makes video games attractive to players and how these aspects can be applied to education as a means to promote student engagement and motivation. Carroll (1982) analysed the design of the seminal text adventure “Adventure”, which in turn led him to propose redressing routine work activities in varying “metaphoric cover stories” in order to turn them into something more intrinsically interesting, and to “urge for a research program on fun and its relation to ease of use” (Deterding et al., 2011; Carroll and Thomas, 1982).

The new millennium saw the introduction of the terms “ludic engagement”, “ludic design”, and “ludic activities” to describe “activities motivated by curiosity, exploration, and reflection” (Gaver et al., 2004), as well as the emergence of a new field called “funology” – the science of enjoyable technology (Blythe et al., 2004) which was inspired by game design and studied “hedonic attributes” (Hassenzahl, 2003) or “motivational affordances” (Zhang, 2008) of “pleasurable products” (Jordan, 2002). Related research focused on using game interfaces and controllers in other contexts (Chao, 2001), creating “games with a purpose” in which game play is employed to solve human information tasks (e.g., tagging images) (Ahn and Dabbish, 2008), and exploring “playfulness” as a desirable user experience or mode of interaction.

The use of video games for educational purposes was also emphasized by the works of Prensky (2001) and Gee (2003). Although these studies were related to game-based learning rather than gamification, their findings form the core of gamification in education: they described the influence of game play on cognitive development, identified 36 learning principles found in video games, and recognised potential advantages of video games in learning such as the value of immediate feedback, self-regulated learning, information on demand, team collaboration, and motivating cycles of expertise (Borys and Laskowski, 2013).

More recently, major corporations and organisations including Adobe (LevelUp, Jigsaw - Dong et al., 2012), Microsoft (Ribbon Hero), IBM (SimArchitect - IBM Global Business Services, 2012), and Autodesk (GamiCAD - Li et al., 2012) consulted with game experts to develop gamified systems that focus on keeping users engaged while learning new software and techniques. Other successful cases of gamification in education include Khan Academy, Treehouse, Udemy, and Duolingo, organisations that provide access to a rich library of content (including interactive challenges, assessments and videos on several subjects) and use badges and points to keep track of student progress. Codecademy is an e-learning platform specialised for computer programming, designed with gamification in mind, while Kahoot is an example of a popular game-based Classroom Response System (CRS, also commonly known as “clicker”) (Fies and Marshall, 2006) that can be played on any device with a browser, both in online and traditional learning environments.

In the context of higher and secondary education, gamification can be applied at vastly different scales to any discipline. At one end is gamification at the micro-scale: individual teachers who gamify their own class structures (Lee and Hammer, 2011) such as Lee Sheldon (2011), a professor at Rensselaer Polytechnic Institute who turned a conventional learning experience into a game without resorting to technology by discarding traditional grading and replacing it with earning “experience points”, while also converting homework assignments into quests (Laster, 2010). At the other end of the scale, a charter school in New York City called “Quest to Learn” uses game design as its organising framework for teaching and learning. Teachers collaborate with game designers to develop playful curricula and base the entire school day around game elements (Corbett, 2010).

To summarise, although the amount of literature on gamification in education is constantly increasing, the wide range of course types, learning preferences, student backgrounds, and socio-economic environments requires more systematic studies of the influence of different gamification techniques in order to assess their efficiency (Barata et al., 2013).
3 Methodology

3.1 Study design and sample

Teaching and assessment of computer programming is considered to be difficult and frequently ineffective, especially to weaker students, as computer programs and algorithms are abstract and complex entities that involve concepts and processes which are often found hard to teach and learn (Olsson et al., 2015; Lahtinen et al., 2005). This sometimes results in undesirable outcomes such as disengagement, cheating, learned helplessness, and dropping out (Robins et al., 2003; Winslow, 1996). Furthermore, most students would not describe classroom-based activities in school as playful experiences. However, research on multimodal teaching has shown that adding more channels for the knowledge transfer can facilitate learning in general (Olsson et al., 2015). Based on this fact and the concepts of the increasingly popular gamification, game-based learning, and serious games movements, the present paper evaluates how gamification affected students of a 12-week university course named “Fundamentals of Software Development” (FSD) via the use of the “Kahoot!” CRS, a modified classroom version of the TV game show “Who Wants To Be A Millionaire?” (WWTBAM), and Codecademy’s online interactive platform.

To reach this objective faculty staff composed of three lecturers conducted a quasi-experimental study over two consecutive academic years at the School of Computing and Technology, University of West London. The sample included a control class (CC) of \(N_{\text{con}} = 54\) students (43 males, 11 females) who attended the FSD course in the first year of the study, and an experimental class (EC) of \(N_{\text{exp}} = 52\) students (44 males, 8 females) who attended FSD in the second year. The participants ranged from 19 to 25 years of age. Additionally, 16 students of the experimental group were regular gamers (31%), 28 played games occasionally (54%), and 8 did not play video games at all (15%).

During the first year FSD followed a non-gamified approach that was similar to the one used in previous years. The syllabus included 12 regular one-hour lectures, 12 two-hour laboratory classes, and 12 one-hour seminars. The theoretical lectures covered Python programming concepts ranging from loops, functions, and object-oriented programming, to GUI applications and videogame development. In laboratory classes students were presented with a series of programming tasks that they had to complete individually during the session, with the tutors offering occasional help. Finally, seminars were used for revision purposes and were delivered via a combination of Q+A and typical lectures. All course materials were uploaded to the institutional Virtual Learning Environment (Blackboard) on a weekly basis. The course evaluation consisted of 6 theoretical quizzes (30% of total grade) and 2 mandatory assessments: a final exam (35%) and a programming project (35%).

An analysis of the student performance data at the end of the first year showed low attendance rates, numerous late arrivals to classes, and lack of interest in the reference material (low number of downloads that increased only before the exams period). In order to address these issues and to make FSD more fun and engaging, teaching methods changed in the second year to incorporate gamification. Literature indicates that educational gameplay fosters engagement in critical thinking, creative problem solving, and teamwork (NMC Horizon Report, 2014). When students are actively engaged in the content that they are learning, there is increased motivation, transfer of new information, and retention (Premkumar and Coupal, 2008). Additionally, the attention span of students diminishes after the first 15-20 minutes into a lecture (Middendorf & Kalish, 1996). Based on these facts, while the course evaluation remained the same, the delivery of the course was gamified as follows.

3.2 Gamification of the course

3.2.1 Formative assessment using Kahoot!

The initial one-hour theoretical lectures were replaced by three 20-minute cycles of a micro-lecture, a formative assessment in the form of a Kahoot! game, and a brief discussion. As mentioned earlier, Kahoot! is a web-based CRS (Hwang et al., 2015) that uses colourful graphics and audio to temporarily transform a classroom into a game show, with the instructor acting as the show host and the students being the competitors. Every week the instructor created three Kahoot! games based on the topics that were going to be covered in the three micro-lectures of the upcoming class. After a micro-lecture was completed, the instructor launched its related Kahoot! game, which in turn generated a unique game pin for each session. Students then
used their own digital devices (tablets, smartphones, laptops) or the class desktops to log-in to the game, enter the game pin, and create a username that would be displayed as the game progressed. Once everyone had joined the game, the instructor’s computer, which was connected to a large screen, displayed a set of 5 MCQs for students to answer on their devices. Each answer was transmitted to Kahoot!’s online processing unit (server) which analysed it and rewarded students with points according to their accuracy and response time (Figure 1). Between each question Kahoot! showed a distribution chart of the students’ answers, thus allowing the instructor to receive immediate feedback on whether concepts had been understood by the whole class or required further elaboration; in the latter case, he paused the game and offered any required explanations. Consequently, a scoreboard revealed the nicknames and scores of the top five responders, and at the end of the game a winner was announced and received some candy as a reward.

Figure 1: “Kahoot!” in-game screenshot

Following the game’s completion, the instructor discussed briefly all answers to each question and downloaded a spreadsheet of the results in order to get an overview of the individual student and overall class performance. Each student’s score was updated every week and was entered to a leaderboard webpage, which was publically accessible through Blackboard and displayed enrolled students in descending order according to their total points. This visual display of progress and ranking provided students with direct feedback on their performance against both their own goals and the performance of their peers, while also serving as instant gratification. The thinking behind this decision was that rankings tap into people’s natural competitiveness and encourage them to do better, which might motivate students to study more by the desire to improve their position (Natvig et al., 2004).

3.2.2 Collaborative problem solving with “Who Wants To Be A Millionaire?”

The one-hour revision seminar was also changed; the combination of Q+A and lectures that took place during the first year was replaced by an open-source implementation of WWTBAM, a television quiz show that offers a top prize of $1 million for answering correctly successive MC questions of increasing difficulty (Figure 2).

Figure 2: “Who Wants To Be A Millionaire?” in-game screenshot
The version of the game used in the classroom featured 540 Python-related MC questions (3 sets of 15 questions per week), which were created by the instructors through a straightforward process that required the editing of a simple text file (Figure 3).

For logistic purposes the class was randomly divided into four groups of 13 students (11 male, 2 female) who attended a separate seminar every week for a total of 12 weeks. During the first seminar each group was randomly split into three teams of 4-5 contestants that remained the same for the duration of the course, and then the gaming activity started as outlined below.

Each team was seated in front of the class facing the screen with their backs to the audience so that they could not receive any unsolicited assistance. Students were then asked 15 increasingly difficult questions on Python programming which covered a different topic every week. Since some of these questions were also scheduled to appear in the 6 theoretical quizzes, in fairness to the team of student contestants, all other students in the class were instructed to put away their note-taking materials for the duration of the game. This also enhanced the perception that the class was taking a break.

Although there was no official time limit to answer a question, each game’s duration was limited to 20 minutes in order to give all teams the opportunity to play once during the seminar. Questions were multiple-choice: 4 possible answers were given and the team had to collaborate, reach a consensus, and give a single response. Additionally, at the beginning of each game contestants were presented with an aid of three lifelines:

- **Poll The Class:** All students provided their answers for a particular question by raising their hands and the percentage of each specific option as chosen by the class was displayed to the contestants.
- **50/50:** The game eliminated two incorrect answers, thus leaving contestants with one incorrect and the correct answer to choose from.
- **Ask A Friend:** Contestants had 30 seconds to read the question and answer choices to a non-team classmate, who in turn had the remaining time to offer input.

After viewing a question, the team could respond in one of three ways:

- Refuse to answer the question, quit the game, and retain all points earned up to that point.
- Answer the question and, if their answer was correct, earn points and continue to play, or lose all points earned to that point and end the game if incorrect. However, the $5,000 and $100,000 prizes were guaranteed: if a team got a question wrong above these levels, then the prize dropped to the previous guaranteed prize.
- Use a lifeline (Ask A Friend, Poll The Class, or 50/50).
The game ended when the contestants answered a question incorrectly, decided not to answer a question, or answered all questions correctly (Figure 4). All answers to each question were conscientiously reviewed for the entire class as the game proceeded. This discussion of the relative merits of the various provided answers was an integral part of the learning process that took place during the execution of the game.

Figure 4: “Who Wants To Be A Millionaire?” game procedure

At the end of every seminar, newly earned points were added to the points carried from previous weeks. The whole scoring process was done manually, with points being collected by faculty and then added to a leaderboard webpage on Blackboard, which showed the team rankings for every group and provided an entry point to the gamified experience. After the twelve seminars were completed, the leading team won the title of “Pythonista of the year” and received chocolate bars as an award. Finally, in order to promote self-assessment and allow students who missed the seminar sessions to experience this alternative form of learning, the game and its latest set of questions became available for download at the end of every week.

3.2.3 Practising programming skills with Codecademy

Founded in 2011, Codecademy offers free coding courses tailored for the new computing syllabus in the UK in a number of programming languages, including Python, JavaScript, HTML/CSS, jQuery, Ruby, and PHP. Additionally, it serves as a competitive virtual classroom that allows students to track their peers’ achievements and work to match or outdo them. The programming courses are organised into sections containing a series of interconnected exercises which in turn include an educational text introducing the related topic, instructions that tell students what to do, and the actual interactive exercise to be completed. Students earn points for completing each exercise and every completion of a lesson is registered as an achievement. Other achievements include the maximum number of points earned in one day, the maximum number of days a student logs-in in a row etc. Badges are also awarded for attaining specific number of points, exceeding a streak length, or completing certain lessons or courses (Swacha and Baszuro, 2013). These gamification features have been crucial to making Codecademy one of the most popular online education providers with over 24 million users to date (Richard Ruth, 2015) and were the main reason behind selecting it as the delivery platform for the programming exercises.
In the first laboratory session instructors created an “FSD Class” containing 36 lessons of Codecademy’s Python track that were mapped to the syllabus of FSD. Students were then asked to sign up and create a pupil account, which was used to enrol them to the FSD class. From that point lab sessions proceeded as follows: every weekly session began with a five-minute introduction to the exercises for the day, and then students were required to complete a certain number of Codecademy lessons based on the topics that had been covered until then. Each lesson was broken down into bite-sized chunks and comprised practical exercises accompanied by notes that explained the programming techniques and terms used. After reading the exercise instructions, students would type in their Python code to the code window, submit their code for execution, and see its output in a separate window (Figure 5). If the code were erroneous, they would receive an error message and would have to try again. Once they managed to solve the exercise, they would earn points and proceed to the next lesson. Students who were not able to finish on time could continue the lessons independently and at their own pace at home, while students who finished early and wished to further their programming skills were provided with additional exercises.

Figure 5: Codecademy’s lesson screen

The Codecademy platform provided students with direct feedback on their progression via graphical representations such as completion indicators for each lesson and for the overall course, badges and points for various achievements etc. (Figure 6). This served as instant gratification and offered an added dimension to learning, as students could track their peers' scores and try to surpass them. Additionally, Codecademy’s “Pupil Tracker” feature allowed instructors to track student progress, including percentage completion, badges, and last log-in dates, as well as to measure students’ courses and tracks in comparison to one another (Figure 7).
In an effort to motivate students to complete the exercises as quickly as possible, the lecturers set a number of different challenges, e.g., highest score achieved in 1 and in 4 weeks, fastest student to reach 50, 100, and 200 points etc. However, no actual physical rewards were given to the winners. The rationale for this decision was to allow faculty staff to evaluate whether the aim of winning a challenge was in itself enough as intrinsic motivation for students to complete their tasks. Each challenge had its own leaderboard, which was made accessible to the students through Blackboard. At the end of each week, staff used the Pupil Tracker to download the spreadsheet with the students’ progression and updated the leaderboards accordingly. The devised challenges motivated the majority of the students to perform on a weekly basis, thus engaging them with programming activities throughout the semester.
4 Results

To ensure that the gamified approach encouraged students’ active participation in the educational process, formative and summative assessments of student engagement were performed using the following methods (Jennings and Angelo, 2006):

- Observation of student behaviour;
- Online survey exploring the effects of gamification in the classroom;
- Students’ self-report of activity through focus groups and semi-structured interviews;
- Collection of administrative data such as student attendance, late arrivals to class, number of reference material downloads, completion rate of lab exercises, and academic performance.

4.1 Observation of student behaviour

In regards to classroom observation of student behaviour, the majority of the EC students demonstrated the following characteristics during all seminars, lectures, and laboratory sessions, which are considered immediate indicators of engagement (Franklin, 2005; Mandernach et al., 2011):

- Actively listened, focused attention and made eye contact;
- Responded to the instructors’ prompts;
- Actively participated in the WWTBAM and Kahoot! games, and in the Codecademy challenges;
- Questioned, explored, brainstormed or discussed the WWTBAM and Kahoot! question topics with their peers and instructors;
- Utilised decision-making or problem solving skills in questioning and responding;
- Demonstrated body language that was open and relaxed with appropriate smiles or laughter.

4.2 Online survey exploring the effects of gamification in the classroom

To gather quantitative feedback about the effectiveness of the gamified experience, all EC students \( N_{\text{exp}} = 52 \) completed a 15-question online survey at the end of the semester. Every question had 5 possible answers measured on a Likert scale of 1 (Strongly Disagree) to 5 (Strongly Agree).
According to the weighted Likert scale average shown in Figure 8, students mostly agreed that the classroom games made learning fun and would like to see them introduced to other modules as well. Students were also generally motivated to attend classes and arrive on time, a finding that was also supported by the administrative data collected at the end of the course. Most students communicated with their peers while playing and believed that performing well in the games increased their self-confidence. Additionally, they were not intimidated by the use of leaderboards and some of them even studied the course material on a weekly basis in order to appear high in the leaderboard rankings. The discussions about the correct and incorrect answers after every question (i.e., why wrong answers were wrong, and right answers were right) were satisfying. Surprisingly enough, there were mixed opinions about getting some tangible rewards, such as translation of game points into actual marks for module assessments. Finally, most students considered gaming a valuable use of instructional time as they felt it helped them improve their analytical and problem-solving skills.
4.3 Semi-structured interviews for in-depth student feedback

To get extra insight into the survey results, qualitative research was conducted in the form of focus groups and semi-structured interviews with a small number of students, featuring questions on collaborative learning, cognitive development, and development of personal skills. As demonstrated by the following sample of responses, the overall reaction by interviewees was extremely positive:

- “I know that I have learned from watching other people play WWTBAM, as well as through playing myself.”
- “I feel great when I know all the answers. Bragging rights are a plus, too.”
- “It makes you feel like you’ve learnt something when you complete a lesson in Codecademy.”
- “Seeing my name at the top of the leaderboard made me feel smart and proud.”
- “Although I am rather shy and quiet as a person, playing WWTBAM boosted my confidence and made it easier for me to collaborate with my classmates.”
- “At last I was allowed to use my iPhone in the class, even if it was for educational purposes.”
- “I enjoy Kahoot! because it’s always fun to beat your classmates.”
- “Lectures don’t feel boring anymore.”

4.4 Analysis of the administrative data

As a means of gauging student persistence, interest, and effort in the gamified classes, there was a comparison of the attendance and the late arrivals (students arriving to class with at least a 10-minute delay) among the control and the experimental classes (Figure 9).

Average class attendance for CC was 65% (=35 students), while EC had an average class attendance of 78% (=42 students). Additionally, an average of 4 to 5 CC students and 1 to 2 EC students arrived to class late every week, respectively. Both findings suggest that gamification motivated EC students to be more punctual and attend classes more often than their CC peers.

In regards to the reference material, every week the instructors uploaded two compressed files: the first one contained the lecture notes and handouts, and the second one contained further reading material (book chapters, journal papers, selected articles, blog posts, and other optional readings). As documented in the number of the reference material’s weekly downloads, it can be argued that CC students demonstrated a relative lack of interest with an average of 1.2 weekly file downloads per student (an average of 65 total downloads per week), which spiked only during the two weeks preceding the final exams; in comparison, every EC student downloaded 1.7 files every week (an average of 89 total downloads per week) without showing any significant deviations (Figure 10). When combined with the survey’s results, this could suggest that EC students were motivated to download and study the course and further reading material every week in order to perform well in the classroom games.
While the CC completion rate of the practical exercises remained roughly around the 50% mark for every laboratory class, EC students showed a small but steady weekly increase in their completion rate, which might indicate that the weekly challenges motivated them to try harder so as to complete their exercises and improve their programming skills. Finally, EC had the best overall academic performance with an average final grade of 61% compared to CG’s 53%. However, due to the relatively low number of participants, additional studies are needed to identify possible correlations between gamification and academic performance.

5 Conclusion and future work

The present study explored how the application of gamification in a computer-programming course could affect the learning experience and the students’ motivation, recall ability, and performance. The aforementioned findings suggest that using a multi-dimensional gamified learning approach has successfully achieved the pedagogical goals outlined in the introduction. Based on the concepts of the increasingly popular gamification, game-based learning and serious games movements, it gives teachers and students the opportunity to experience first-hand how game mechanics can be used to make learning fun and addictive. Coupled with effective pedagogy, games can offer a more effective and less intrusive measurement of learning than traditional assessments.
Both Kahoot! and WWTBAM serve as an opportunity for instant application of knowledge and reinforcement of learning outcomes. They allow common programming language misconceptions to be revealed and explored, while also using similar game mechanisms to make students feel good about their accomplishments and overcome their personal records.

More specifically, Kahoot! provides students with the opportunity for self-assessment through a fun and engaging atmosphere, which allows them to master new programming concepts relatively quickly. It is a great tool for learning terminology and can be also used to introduce a topic, as it can help instructors discover what the students already know and where they should focus their instruction on. Additionally, the findings are comparable to those from other studies which show that the use of CRS increases students’ attendance, attentiveness, enthusiasm, confidence, and in-class participation (Duncan, 2005; Suchman et al, 2006; Bullock et al. 2003; Roschelle et al., 2004; Wit, 2003). As for WWTBAM, it requires students to compare and discuss their answers with their teammates in order to come to a consensus regarding the answer, thus improving communication efficiency and honing important employability skills such as problem solving, critical thinking, and collaboration. In both games students not only reported more enjoyment in their class, but also stated that confidence in their own learning had grown, while instructors noticed an increase in their own ability to respond to students’ misconceptions.

This mix of individual and group competition in the classroom catered to the needs of diverse students, some of which preferred to initially develop their coding skills alone while others performed better in groups. As the semester progressed though, it was noticed that the students’ engagement decreased slowly in the Kahoot! sessions; on the other hand, the engagement for WWTBAM remained unchanged. This could be attributed to the fact that students competing at individual level in Kahoot! began to lose interest once they trailed behind in the leaderboard. Another concern from the teaching staff’s point of view was the limited length of the multiple-choice questions and answers in both games, which made their authoring quite challenging.

The use of Codecademy’s points and badges as the sole motivator for completing the practical exercises also provided some interesting insights. Although students were intrinsically motivated to complete their exercises and generally performed better than their CC peers, they expressed some concerns about the lesson contents, saying that some lessons were not always a good fit to the FSD syllabus, lacked clear instructions, and had ambiguous explanations and vague error messages. As a result, students who struggled on a particular aspect of programming due to the poor quality of that particular set of lessons tended to associate that aspect with being difficult to grasp and master, when it was not necessarily so. A possible yet rather demanding solution to this problem would be to provide students with a more personalised experience by developing lessons specifically for the FSD syllabus. Additionally, data analytics could be used to identify which programming concepts are more challenging for students, so as to give the latter opportunities for more practice.

Whilst the results are encouraging, the authors acknowledge that the limited nature of this study does not preclude the possibility that the improvements in student engagement are simply the result the short-term “novelty” factors generally associated with the introduction of new technology and learning techniques. Further study is needed to assess whether the increased student engagement suggested by these methods is sustainable and applicable to other subjects.

**References**


Exploring Media Literacy and Computational Thinking: A Game Maker Curriculum Study

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Abstract: While advances in game-based learning are already transforming educative practices globally, with tech giants like Microsoft, Apple and Google taking notice and investing in educational game initiatives, there is a concurrent and critically important development that focuses on ‘game construction’ pedagogy as a vehicle for enhancing computational literacy in middle and high school students. Essentially, game construction-based curriculum takes the central question “do children learn from playing games” to the next stage by asking “(what) can children learn from constructing games?” Founded on Seymour Papert’s constructionist learning model, and developed over nearly two decades, there is compelling evidence that game construction can increase student confidence and build their capacity towards ongoing computing science involvement and other STEM subjects. Our study adds to the growing body of literature on school-based game construction through comprehensive empirical methodology and evidence-based guidelines for curriculum design. There is still debate as to the utility of different software tools for game construction, models of scaffolding knowledge, and evaluation of learning outcomes and knowledge transfer. In this paper, we present a study we conducted in a classroom environment with three groups of grade 6 students (60+ students) using Game Maker to construct their own games. Based on a quantitative analysis and a qualitative discussion we organize results around several core themes that speak to the field of inquiry: levels of computational literacy based on pre- and post-tests; gender-based attitudes to computing science and programming based on a pre- and post-survey; and the relationship between existing media literacy and performance in programming as part of the game construction curriculum. Significant results include some gender differences in attitudes towards computers and programming with boys demonstrating slightly higher confidence and performance. We discuss the complex reasons potentially contributing to that, particularly against a diverse ecology of overall media use, gameplay experience and access to technology at home. Finally, we theorize game construction as an educational tool that directly engages foundational literacy and numeracy, and connects to wider STEM-oriented learning objectives in ways that can benefit both boys and girls in the classroom.

Keywords: game making, STEM, coding, Game Maker, digital literacy

1 In pursuit of “21st century skills”

An ongoing challenge of the 21st century is ensuring everyone has the requisite skills to participate in a digital, knowledge-based economy. This is increasingly difficult under conditions of austerity in both K-12 and higher education, at a time when there is significant need for skilled labour in technology and computing fields in particular. Despite widespread enthusiasm for “21st century learning,” researchers and policy makers around the globe are still trying to articulate exactly what constitutes this term (Media Awareness Network 2010), while public education generally is being criticized for not adopting it (Francis 2012; Lynch 2013). There is, for example, no specific curriculum provision regarding what 21st century learning should entail and how that should inform K-12 schooling, though there is widespread and growing agreement that digital games figure somewhere in that landscape (Gee 2005; Salen 2007; Squire 2011). Digital games are increasingly at the forefront of conversations about ways to address student disengagement (Gee 2003; Rieber, LP 1996; Rupp et al. 2010) and ways to foster 21st century learning and skills (Barab & Dede 2007; Steinkuehler 2008; Squire 2011). That research concentrates on playing digital games, whether those are commercially made or made especially for education. Less prominent has been research focused on the design and development of games as a means to support critical competencies like creative problem solving, collaboration, and programming skills (Carbonaro et al. 2010; Denner 2011; Denner & Wenner 2007; Papert 1993). Designing and making digital games, this prior research suggests, can provide an ideal framework for operationalizing 21st century learning: creating digital artifacts entails technical, computational and aesthetic forms of activity whose success depends on bridging between arts and sciences—an intersection increasingly characteristic of the contemporary job market and effective participation in social life.
One of the main motivations for bringing game design and development into the fold of STEM curriculum planning concerns the need to introduce and familiarize youth to the principles of computation, design thinking and procedural logic, from an earlier age than is currently practised. The context for this is a growing acknowledgement among educational researchers, computer scientists and teachers that ‘computational thinking’ and algorithmic logic ought to be considered a kind of ‘core literacy’ that needs to be incorporated into the school curriculum alongside numeracy, textual literacy and scientific thinking (diSessa 2000; Wing 2006). Computational thinking can also be located alongside a range of other competence-based technological ‘literacies’ discussed in popular education blogs, that include ‘making’ or tech prototyping, fostering of applied ‘creativity,’ as well as ‘design thinking’. While Papert’s work in the 1980s saw the emergence of the first user-oriented Logo coding language developed specifically with educational goals in mind, it has only been in the last five to ten years that a plethora of drag-and-drop programming environments for children have become readily and easily available. During that time there have been numerous improvements to the user interface and functionality of these programs, targeting specific age groups and in many cases making tools available on the web as part of online sharing communities of practice. One of the most pertinent underpinnings of contemporary education research into using game construction software in the classroom is addressing the systemic problem of girls’ impoverished representation in computing science and technical fields. Such studies aim to deliberately engage girls and other marginalized youth groups in coding activities, and counter negative associations and lack of confidence that might hold them back from approaching and benefiting from ongoing computer programming instruction. A central pedagogical concern with regard to teaching game construction as an entry-level form of computer programming centres around defining and operationalizing “computational thinking” as a core curricular concept, and identifying how and when to introduce it into the classroom. Additional concerns involve what type of instruction is required and which tools are best suited to achieve these cognitive objectives.

2 Definition and ‘cognitive objectives’ of computational thinking (CT)

Wing (2006) defines CT as “reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation.” Yadav et al. (2014) define CT as a “mental activity for abstracting problems and formulating solutions that can be automated” while Cuny et al. (2010) define it as “the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent”. According to Denner, Werner and Ortiz (2011), “algorithmic thinking involves defining a problem, breaking it into smaller yet solvable parts, and identifying the steps for solving the problem.” As part of this, students must model the essential characteristics of the problem while suppressing unnecessary details. In the process, “finite sequences of instructions are coded to operationalize the modeled abstractions.” From a review of the field in Grover and Pea (2013), the following is a standard list of learning objectives or computational constructs that ought to be covered in some form in instructional designs of entry-level computing:

- Abstractions and pattern generalizations (including models and simulations)
- Systematic processing of information (proceduralization)
- Symbol systems and representations
- Structured problem decomposition (modularizing)
- Iterative, recursive, and parallel thinking
- Conditional logic
- Debugging and systematic error detection (pp. 39-40)

A major challenge here is translating these constructs to both affordances of existing game development tools and to specific instructional designs and learning objectives. A number of contemporary studies, for instance, have published extensive breakdowns of tool-specific available actions, modifications, as well as procedural and conditional logic sequences that correspond to top-level computational constructs (Carbonaro et al. 2010; Denner 2011; Denner & Wenner 2007). However, less explicit are the particular pedagogical underpinnings of instructional design by which game construction is introduced and implemented in the classroom within the larger context of mathematics and science (STEM) instruction. Specifically, some of the concerns that need to

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1 Arguably two of the oldest and most widely used drag-and-drop coding environments for early school education are Scratch https://scratch.mit.edu/ and Alice http://www.alice.org/
addressed include the scaffolding, assessment and transfer of both computational terminology and applied coding skills.

3 Assessment, scaffolding and transfer of conceptual skills

A standard approach in establishing the efficacy of a particular curricular program is using a pre- and post-test. Additional study measures include implementing different scaffolding designs (e.g. written materials or direct instruction prior to game construction activity), and exercises that specifically evaluate domain transfer and cross-domain transfer of particular learning content or skill. Depending on the research objectives related to computational thinking instruction (CT) different studies adopt different pre- and post-test measures. For instance, given existing evidence that programming performance is related to confidence and attitudes to computing science (CS), there are several instruments that specifically test (using Likert-scale questions) confidence and attitude constructs related to CS (Hoegh & Moskal 2009; Heersink & Moskal 2010). Additionally, Seaborn and colleagues (2012) implement a programming-specific pre/post-test that not only evaluates domain-level knowledge related to computational terminology, but also responses to semantically correct programming language (commands written in programming code). A large part of assessment is of course analyzing and evaluating the game artefacts that students create in terms of complexity and the incorporation of specific computational elements. The problem of assessing the transfer of computational knowledge was addressed as early as 1988 (Klahr and Carver). Werner, Denner and Campe (2012) propose a de-bugging game as a gamified form of assessment that not only looks at correct solutions, but the process of troubleshooting and alternative approaches.

Assessment is also a function of the study design including the overall timeframe of instruction and scaffolding activities (Lye & Koh 2014). In this sense, and given the practical difficulties of securing ‘classroom time’ as part of regular school curricula, there is quite a lot of variation in the structure and framing, as well as choice of programming environment, in educational research that takes up game construction as a way of teaching computational thinking (CT). Examples of this include Carbonaro et al. (2010), who used ScriptEase, a module-based drag-and-drop game construction program, for two 6-hr direct instruction workshops at University of Alberta, in addition to 6 more hours at school for kids to finish their games. Denner, Werner and Ortiz (2011) worked with girls in an after-school club setting for over 14 months (1-2hrs a week), designing a series of six different genre games in Stagecast Creator, another module-based drag-and-drop environment. Seaborn et al. (2012) adopted the structure of a ‘design camp’ utilizing Game Maker with high school teams in six modules each lasting several months; their study measured self-efficacy, perception of helpfulness of classroom activities, and understanding of computational concepts.

4 Teaching coding with Game Maker: A case study

This project is a research-based challenge to the now widely questioned but surprisingly persistent presumption that students in today's classrooms are all by default 'digitally native' (Prensky 2001), and that those 'digitally native' children are learning just by playing digital games (Prensky 2005). In actuality, ‘digital nativity’ is looking markedly gendered, raced and classed (de Castell, Boschman & Jenson 2008), and the educational use of digital games to advance 21st century learning is turning out to demand a lot more than just playing them. Just being familiar with digital technologies and using them in one’s everyday life does not necessarily translate into skillfully using them for learning (Livingstone, 2010). This study recognizes that in the contemporary media landscape, familiarity with digital gameplay can represent for many young people their entry point into acquiring the foundational digital skills demanded by a global knowledge economy. It builds on the familiar game medium as a ‘gateway’ to study the development of critical digital literacies not through digital game play on its own, but through a ‘production pedagogy’ in which gameplay is integrally co-engaged with the design and development of digital games.

One of the aims of this study is to investigate the question of whether gameplay experience and general media literacy in childrens’ lives relate to their ability to participate and benefit from game construction activities in the classroom. This question is inextricably linked to the larger context of STEM instruction and in that sense this study will contribute to research on game design as a ‘gateway’ to STEM. This might, moreover, be a way to effectively re-fuse the digital divide which the survey will document and track for the duration of the project. Finally, we set out to explore, beyond simply celebrating the introduction of game construction in the
classroom, specific instructional designs that can help and support students, not only in overcoming confidence-related barriers to entry into computing science later in their education, but also in supporting and supplementing their grade-specific STEM knowledge through its application in the domain of game-making.

4.1 Study Design

This study took place in a very large elementary school (with over 750 children) in Ontario, Canada. Ontario does not currently have any mandatory computer science related curricula at the grade 6 level. We chose to work with Grade 6 students as much of the work done previously (see Carbonaro et al. 2010; Denner 2011) suggests that grades 6 to 7 is the time many students begin to make choices about what courses they will take at the high school level and beyond. Because there is currently no equivalent curriculum in Ontario, we had to negotiate classroom time with the participating principal and teachers, meaning that in this case we used time that otherwise would have been designated for Language Arts. Our rationale for this is that we were concentrating on learning a new piece of software that also meant students learned new vocabulary and new concepts related to programming. In the end, we were able to negotiate working with the full grade 6 complement in the school (3 classes, 67 students), replacing their curriculum for a period of 1.5 hours over 6 consecutive days, in addition to a full day of curricular programming in a fieldtrip to a local university. In total, the participating students had approximately 15 hours using Game Maker and of that, approximately 4-5 hours were direct instruction. Nearly all students worked in pairs to create their games. Peer-based programming instruction has been shown in previous studies to be positively correlated with the retention and application of new material (Peppler & Kafai 2007). We also wanted to scaffold peer support for students so that they did not have to rely on the researchers to answer questions and to help move their games along.

4.2 Operationalizing Computational Constructs

In order to create a usable instructional design for grade-appropriate computational literacy curriculum we had to translate higher-level frameworks of computational thinking such as ‘decomposition,’ ‘parallelism’ and ‘abstractions and pattern generalization’ constructs into operational computer science vocabulary and operations. In particular, amidst increasing critiques of drag-and-drop game design as a form of computational literacy instruction (Duncan, Bell & Tanimoto 2014) we wanted to depart from bottom-up ‘sandbox’ environments such as Scratch or Alice and attempt grade-appropriate instruction directly using code-window semantic programming. Since Game Maker Studio provides both drag-and-drop and semantic coding (though, arguably it is skewed towards coding) we landed on using this tool as one of the more versatile products that offer low/mid-entry and high ceiling opportunities for game development. It is a tool that relates more transparently to computational constructs and the practice of object-oriented programming, and can be adapted for computational instruction at a variety of (upper) grade levels as well. The following table represents our instructional framework across the specific software domain of Game Maker as they link to higher-level computational constructs and vocabulary.

<table>
<thead>
<tr>
<th>CT constructs</th>
<th>Definition / Domain knowledge</th>
<th>Game Maker syntax examples</th>
<th>Computational Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>Containers for storing values so that values can be used and modified in other parts of the program</td>
<td>direction = 180; speed = 4;</td>
<td>Variable, value, object, instantiation, syntax, rate of movement, direction</td>
</tr>
<tr>
<td>Operations</td>
<td>Mathematical operations with variables or other parts of the program that cause game state changes</td>
<td>score = score + 1; x = x – 7;</td>
<td>Mathematical operations, Cartesian (x/y) coordinates, syntax</td>
</tr>
<tr>
<td>Functions</td>
<td>Built-in computational objects, modifiable constructs that cause specific game actions and state changes</td>
<td>instance_destroy(); move_bounce_solid(false);</td>
<td>Function, Boolean logic (true/false), syntax, attributes, parameters, nested operations, placeholder</td>
</tr>
</tbody>
</table>
| Conditionals  | Statements that evaluate a game state and cause other game actions, operations, variable changes etc. to take place | if place_meeting (x, y + 1) {
    gravity = 0.01;
} else {
    gravity = 0;
} | Boolean evaluation (if/then/else), conditional logic, branching and nesting, truth value, queries |

Table 1. Computational instruction framework
4.3 Instructional design: scaffolding and facilitation

In previous iterations of this type of study – game design camps with grade school students – we typically relied on heavy facilitation and one-on-one work with students or project peer groups to help students complete a functional and polished version of their game idea (see Fisher & Jenson, Forthcoming). We still used Game Maker, however our curriculum was based on drag-and-drop commands and the instructional format was after-school clubs rather than classroom-based instruction. The system of instruction we used formerly comprised of one extensive follow-along tutorial of Game Maker’s sandbox game the Brick Breaker followed by unstructured game design time for kids to work on their own game ideas. For this iteration of research, particularly given that it took up valuable classroom time, we scaffolded coding instruction with a series of direct follow-along lessons where participants learned new vocabulary and practiced applying new programming constructs in appropriate chunks of material. The rest of each session was spent working on their own game, adapting and modifying elements that were just covered in their own design. Key to our curriculum design in this study was the pacing of instruction and material, and the incremental introduction of computational concepts. First we introduced the concept and application of variables, then the role and syntax of operations, followed by the concept and use of functions (including in-depth self-help strategies using Game Maker’s reference guide for game programming). Finally we introduced the syntax and function of conditional statements, all the while reinforcing previously learned vocabulary, reiterating the logic and relationship between game events and game actions (input and output).

As part of the curriculum we built in the option for participants to look into several developed example games and copy and adapt code from them as a kind of ‘ecological’ approach to coding instruction, given that copying and adapting code is foundational to efficiency in programming in the workplace (Duncan, Bell & Tanimoto 2014). In this much more structured and scaffolded game construction curriculum, our vision was of research facilitators assisting with software/interface issues (since Game Maker has a bit of a learning curve), and helping to guide participants in design and programmatic challenges through case-by-case directed instruction, rather than dictating or writing code for them. To enable this model of self-directed learning we enforced an “Ask 3 before you ask Me” rule where kids had to look up a question they had in the Game Maker help, or ask a peer, before they turned to a research facilitator.

4.4 Data Collection

Prior to the study, every participant was given a media literacy and attitudes questionnaire, as well as a pre-test designed to evaluate their existing knowledge of computer science concepts such as variables, operations and functions. Following the study, in order to determine what if any attitudinal changes might have occurred, a post-test was administered that was identical to the pre-test, and a short questionnaire that repeated the same attitudinal questions from the medial literacy and attitudes questionnaire. In addition, daily field notes were taken by at least two researchers who were on hand for the duration of the study, that included short video clips and photos as students worked on their games. To capture the progress that participants were making daily as well as to gauge how much and what type of help participants were receiving from researchers, we used Chronolapse, a software that records an image of the computer’s screen along with a webcam image every 15 seconds. In total, we generated 256 Chronolapse videos of approximately 1.5 hrs duration for each and recorded 36 qualitative fieldnotes of each classroom session day.

5 Results and Discussion

Given that the study and data collection are still ongoing, in this paper we report preliminary results in relation to areas of critical discussion related to the issues raised earlier. As well, we discuss some preliminary correlations, which are evaluated on an ongoing basis with a statistical analysis using the chi-square test of independence for binomial variables and paired t-tests for continuous variables. Overall, the classroom-based instructional model seemed to function well for grade 6 students working in pairs, who were able to create playable complete games using Game Maker within the 6 classroom sessions + 1 extended university-based field trip. Not only did students design and code their games with minimal facilitation, but their content knowledge of basic computational terminology, as well as Game Maker domain knowledge, improved from an average of 6.7 to an average of 9.3 (out of 16). In the following sub-sections we discuss additional preliminary data organized around several critical areas: assumptions about pre-existing video game competence and computer-based (and computational) knowledge; the relationship between gender, confidence, and attitudes

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1 http://sandbox.yoyogames.com/games/120704
towards computer programming instruction; and preliminary results about gender differences in computer
programming performance in the context of game construction. Finally we comment on some initial
impressions related to the study design, facilitation and classroom-based context utilized here.

Figure 1. Classroom set up and kids working on game design and game programming

5.1 Digital Know How: Surveying Media Use and Playing Games

In terms of general media use (based off the media questionnaire), we made sure to cover a wide array of
media practices and technologies that students might use: personal mobile technologies; different types of
computers; gaming devices; broadcast media; social media portals; game genres; and electronic
communication platforms. The results are as follows: boys and girls are similarly likely to use social media, and
almost everyone reported YouTube as one of their top websites/social media sites to visit at home, closely
followed by Facebook and Instagram. Girls are slightly more likely to report that they use online
communication tools such as Skype or FaceTime, as well as more likely than boys to frequent the micro-
blogging platform Tumblr (non-significant result). While most respondents reported regularly playing
videogames, boys are significantly more likely to play online multiplayer and high-end console games, and girls
a bit more likely to play puzzle or role-playing games on the Wii platform, have access to tablets, and play
mobile games. In terms of significance, a chi-square test of independence indicated that the relationship
between gender and daily game console use was significant, with boys much more likely to use gaming
consoles, \( X^2 (1, N=65) = 10.76, p < .01 \). Some of these gender differences in access to and use of computers and
gaming consoles likely speaks to cultural advertising that targets boys for high-end consoles such as XBOX and
PlayStation, while establishing a wider audience for ‘educational’ tools such as the Wii Series or the iPad.

Of the participants who reported that they did not own gaming platforms or played games, the majority were
girls. These nuanced gender differences were also noted by researchers in the classroom during instruction,
with boys much more likely to raise their hand to answer questions related to gaming and computers, and girls
much more likely to volunteer answering questions about mathematics, language and other STEM content
that figured into computational concepts.

In terms of device use at home, which relates to overall media literacy and technological ease and
competence, there was only one statistically significant difference in the relationship between gender and
daily laptop use with a chi square of \( X^2 (1, N=65) = 4.53, p < .03 \), indicating that female students reported that
they were more likely than male students to use a laptop daily at home. This means that the majority of access
and frequency of use of everyday technologies such as broadcast media, personal devices, popular websites
and social media, are more or less equally distributed among male and female students, with the more
interesting differences being in the content consumed/interacted with: more high-end, strategy and virtual
reality-based games in the case of boys, and more versatile, casual puzzle and motion-based games in the case
of girls. Potentially related to these statistics of media and video game use (however, non-statistically
significant in this study), girls had a slightly lower average score on the computational literacy pre-test
compared to boys, and boys’ post-test scores improved significantly more than girls’ scores (see Figure 2). That
said, a more nuanced look into the data reveals that girls tended to have more consistent average scores,
whereas boys’ competence was split between those who had very little knowledge and those who had extensive prior experience with computing and gaming.

Figure 2. Computational literacy pre- and post-test results by gender

What is interesting here in terms of the oft-assumed relationship between an allegedly tech-savvy generation and an aptitude for computer science, is that reported frequent gameplay activity or specific media technology use did not correlate significantly with either a high score on the computational knowledge pre-test, or with an overall high confidence about using computers and learning programming. A few exceptions, anecdotally, are that playing Minecraft seemed to correlate with higher pre-test scores and overall higher confidence about using/learning about computers; not playing games at all correlated with lower confidence about using and learning about computers and lower pre-test scores. This context both confirms and questions some of the game-based learning assumptions pointed out in past work – namely, that playing video games creates base computational knowledge and confidence about technical computer skills. Our work suggests that playing video games is one important ingredient to creating the conditions for computer programming instruction and computational literacy, however, it can also be said that access to and encouragement to play games and use technology is a core part of home and family socialization, bringing us back to the ‘origins’ question of gender-based differences in technology performance.

Clearly, there is more at play here. For instance, when we look at performance on the computational knowledge pre-test, on average, kids who had higher scores reported less confidence about their ability to learn new computer programs, computational concepts, and troubleshoot computer programs. Conversely, kids who displayed some of the lowest pre-test scores reported some of the highest confidence about working with computers and being able to use and learn new computer programs. This finding is of critical pedagogical importance because it suggests that procedural ‘content’ knowledge about mathematics and computer programming does not necessarily translate into confidence or perceived ability to contend with computational instruction. There are more issues here that warrant further research to better our understanding, specifically around children using computers and engaging in gaming and social media, and if and how these activities support “learning.”

5.2 Gender-based Attitudes to CS in Computer Programming Instruction

To develop and implement a school-wide computational literacy program based in game construction, it is necessary to first examine and understand some of the underlying context of STEM education at the grade 6 level, as well as some of the persistent gender differences in confidence and preparedness in relation to computer work in general. Confidence and attitudes has already been linked in numerous studies (Carbonaro et al. 2010) to actual classroom performance and the ability to learn computer programming, as well as the motivation to continue on this educational track. Given this, an important part of the pre-study questionnaire was gauging self-reported confidence around using computers and learning computer programming, including potentially ‘gendered’ attitudes towards computational knowledge in general. Results collected so far suggest that while both sexes think the other is worse at computer programming, boys were significantly more likely to assess girls’ computer skills as low, whereas girls had mixed evaluations of boys’ capabilities in programming. This trend translates into self-reported attitudes and confidence with regard to computer skills in general and one’s capacity to learn programming (see Figure 3). Girls consistently scored lower in confidence levels than boys, and in particular, they scored significantly lower on confidence in their abilities to troubleshoot computer programs as well as general self-confidence when it comes to computer programming (but not computer use).
Some of the positive findings around attitudes to computer science were that neither girls nor boys reported any social stigma for ‘being good with computers’, and on the whole everyone gave positive scores to the idea of studying computer programming at school, being interested in computers, pursuing computer science further, and having a future career that includes computer work and coding. In terms of pedagogical efficacy, we wanted to ask students what they thought can be learned from games and from programming in the classroom. When asked why they thought computer programming would be good to teach at school, most kids emphasized experiential learning, trial and error, and learning about computers. Girls were significantly more likely to list ‘collaborating with others’ and ‘learning from experience’ which might suggest both an appetite for applied learning (especially if they are not exposed to it at home) and valuing traditionally ‘feminized’ qualities of work such as collaboration. Most kids listed ‘making learning fun’ and ‘learning specific content’ but very few ticked ‘learning about logic’, which might indicate a gap in terms of what students understand computer programming instruction to be outside or inside a school setting.
The post-survey on attitudes to CS (Computer Science) highlights several important trends (see Figure 4). It seems that the experience of being immersed in computer programming instruction for the duration of a week and a half served to temper most kids’ self-reported confidence regarding both computer use and, more specifically, programming. However, once again we observe troubling gender differences: while boys pre- and post-attitudes hardly change, girls’ confidence is observably lower (though not universally significantly so), except in the case where girls felt more confident with their ability to troubleshoot computer problems. This very well may be one of the strongest indicators and prerequisites for performance in computer programming – the confidence and knowledge to solve one’s own problems. So while boys on the average went into the experience with that confidence, and then gained additional instrumental skills, for girls the exercise very much served to develop this type of confidence with computer programs. Since most participants added post-survey comments about their experience, we can also trace their reported impressions in relation to their attitudes and confidence levels. Interestingly, both girls and boys on the whole described the experience as ‘fun’ and ‘exciting’, highlighting the opportunity to do something they’ve ‘never done before’ and learn new skills. At the same time, both boys and girls acknowledged how challenging and difficult coding is – something that was a bit of a surprise to them:

“When I did my own game I felt happy because I never created a game before so I felt excited. I also find it hard like for some of the parts but it was exciting.” (Girl, aged 11)

“My experience making my own game was amazing because I learned a lot of cool things. I also got a chance to see that computers aren’t just for playing games but for making them too.” (Boy, aged 11)

“It took so long to make something seemingly simple. It’s really hard to use when you know nothing about it (the program). So much coding goes into one action.” (Girl, aged 11)

“It is hard and not simple because there are many codes needed and memorized.” (Boy, aged 11)

This newfound awareness of the complexity of computer programming might explain an interesting result with regard to attitudes to gender and specifically girls’ perceived ability to program code. There was a significant difference between male and female students in their attitudes towards girls’ ability to perform well at computer programming, $t(61) = -2.50, p < .05$. Girls’ opinions changed to more strongly endorse the belief that girls could not do well at computer programming; conversely, boys’ opinions changed to more strongly disagree with the belief that girls could not do well at computer programming. In other words, as the quantitative data shows, while girls lost some confidence in their own abilities, boys gained respect and appreciation for girls’ abilities, having worked alongside them and also having been mentored by skilled female game programmers.

5.3 Study Design and Facilitation: Lessons Learned

While we have indicated in another section above that the curriculum we developed included direct instruction for the parts that involved procedural coding using the coding “window” that is available in Game Maker (see Figure 1, left side), we did have to spend quite a bit of time “tweaking” our curriculum while we were developing it. In this section we will briefly detail three primary lessons we learned in this pilot study. First, we found that it was necessary to begin each session with a piece of direct instruction that highlighted the programming concepts we wanted students to practice in their own games. Once that direct instruction was accomplished, we turned the rest of the time over for them to work on their own games, supported by the researchers and a team of facilitators that were trained in Game Maker. Interestingly, we also had to manage the facilitators’ expectations for providing help, as they sometimes provided help by directly fixing code and/or by providing code that the students could not yet know in order to make a game work. Second, we found that we had to do quite a lot of managing of student expectations for the games they wanted to create; all too often they wanted to make games that exceeded their abilities and were not able to re-design their games with their limited abilities in mind. While this is not necessarily a surprising outcome, it was surprising to us how many participants were unfamiliar with just how much is involved in game design, and how demanding their designs were from a programming standpoint. This points back to the lack of any formal curriculum in Ontario with regards to computer programming, and also to the necessity for that at much earlier grade levels. Third and finally, as much as we wanted to create an ‘open design’ experience for participants, in hindsight the fact that we did not assign a game theme or genre, nor insisted that they replicate the game we used to demonstrate core concepts, meant that (for some) the task was overwhelmingly vague. For those who were overwhelmed, we often had them recreate the game that we used
as demonstration, which allowed all of them to proceed with the task, and some to change/hack the game in an interesting way.

6 In conclusion

This paper presents just some of the core findings from a pilot study that made use of a free, commercially available game design program (Game Maker), to introduce children to key computational thinking constructs such as variables, operations, functions, and conditionals, and allow them to practice applying this new knowledge. Overall, participants were enthusiastic users of the tool, and did not struggle in the time we spent with them (for the most part) to stay on task or stay interested in their own game development. While we have not reported here on the affective engagement of our participants, it is in fact a highly relevant outcome of the study, and one that we will elaborate on in future papers, as we also had an opportunity to hear from parents of participating students who reported that their children were keen to continue working on their games outside of classroom time. Based on our preliminary discussion of the data above, there are three primary conclusions that are worth emphasizing. First, as others have pointed out, claims that today’s students are defacto ‘digitally native’ is not the case for all students, nor does it indicate that students have familiarity or even facility with basic computer programming skills and competencies. Second, there are still gender differences in attitude and confidence with computers that in an instructional study such as this can and did affect performance on programming related tasks, not only on the post-test, but also in our many observations of girls during the time we spent with them. In general, girls were less willing to participate in public displays of knowledge (like answering questions to the whole group) and were more likely than their male counterparts to ‘disavow’ their skills with speech acts, such as “I always break the computer”, and “I am not good at computers”. We show that such differences in attitudes can and do affect performance. Finally, our model of a structured curriculum that combines applied work with direct follow-along instruction is encouraging, and we hope eventually replicable in a school district-wide instructional programme. In conclusion, this preliminary analysis has shown that using commercially available game design software, that permits a variety of scalable programming actions in the process of coding and testing a game, is not only a viable way of introducing a middle-school demographic to computational literacy but is an effective means for fostering and supporting STEM related competencies, vocabularies and skills.

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Educational Games in Practice: The challenges involved in conducting a game-based curriculum

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Abstract: The task of integrating games into an educational setting is a demanding one, and integrating games as a harmonious part of a bigger ecosystem of learning requires teachers to orchestrate a myriad of complex organizational resources. Historically, research on digital game-based learning has focused heavily on the coupling between game designs, previously established learning principles, student engagement, and learning outcomes much to the expense of understanding how games function in their intended educational contexts and how they impact the working processes of teachers. Given the significant investments of time and resources teachers need to make in order to conduct game-based learning activities, the foci of past research is problematic as it obfuscates some of the pressing realities that highly affect games' viability as tools for teaching and learning. This paper aims to highlight the demands that the implementation and use of an educational game in formal educational settings puts on teachers' working processes and skillsets. The paper is based on two case studies in which a researcher collaborated with K-12 teachers to use MinecraftEdu (TeacherGaming LLC, 2012) as a classroom activity over a five-month long period. By documenting both the working processes involved in implementing the game into the classroom environment, as well as the execution of the actual game-based classroom activities, the studies identified a wide variety roles that a teacher needs to take on if they are to make games a central part of a school curriculum. Ultimately, the paper highlights the importance of understanding the constraints under which teachers work, and argues that a better understanding of the contexts in which games are to be used, and the roles teachers play during game-based learning scenarios, is a necessary foundation for improving games' viability as educational tools.

Keywords: computers in classroom, distraction, gaming literacy, student diversity, teacher roles, challenges of game-based learning

1 Educational games and teachers

As the body of research that points out the potential educational value of games grows, the interest for including more game-based learning in educational processes has increased (Wastiau, Kearney & Van de Berghhe, 2009). The discussions on the topic frequently highlight games’ intrinsic educational value, such as their experiential nature or their ability to encourage players to master domains through scaffolding and flow-evoking designs. However, while games’ educational values keep being lauded, examples of games being integrated into educational settings are relatively few (Egenfeldt-Nielsen, 2010; Linehan et al., 2011). Previous research on the topic of educational games has heavily emphasized the game artefact and the player-game relationship when discussing the viability and efficacy of digital games as tools for learning (Young et al., 2012). From this epistemological perspective, games are often claimed to have high educational potential, and studies tend to show a positive correlation between gaming activities and learning (Backlund & Hendrix, 2013; Connolly et al., 2012). While conclusions drawn from those types of studies may say something about games’ and e-solutions’ ability to produce learning outcomes, they do not say much about their viability and usefulness as teaching tools in formal settings. As put by Noesgaard and Ørngreen (2015) “only using the fulfilment of pre-defined learning objectives as an effectiveness parameter does not allow developers and researchers to see unexpected and unintended changes in practice that occur as a result of the e-Learning program”.

In the broader field of game research, games have increasingly been studied and described on their qualities as situated activities rather than artefacts in later years (e.g. Eklund, 2012; Stenros, 2015). A similar shift has started to emerge in educational games research, where the structures and components that surround the game artefact are starting to get more attention. For example, studies such as the ones conducted by Greener and Wakefield (2015) and Bourgonjon and Hanghøj (2011) focus more on understanding how organizational cultures and teachers’ literacies needs to be supported if game-based learning and other e-Learning solutions are to be seen as accessible for all teachers and schools. Even though interest is increasing, and the current ISSN 1479-4403 122 ©ACPI

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understanding of games’ viability as teaching tools is becoming more nuanced, the knowledge surrounding the processes that are involved in implementing and using games in formal educational settings is still limited. Calls for more examinations of how e-Learning and games affect teachers’ and students’ processes of working and learning have been made frequently throughout the past decade (e.g. Kirriemuir & McFarlane, 2003; Ross, Morrison & Lowther, 2010; Young et al., 2012). However, examples of empirical work done to understand the practicalities involved in using educational games, such as the tasks teachers need to perform when integrating games into formal educational contexts, remain comparatively rare (Alklind Taylor & Backlund, 2012; Bourgonjon & Hanghøj, 2011; Chee, Mehrrotra & Ong, 2014).

This paper aims to address that knowledge gap, and provide a pragmatic explanation of the lack of widespread game integration in the education sector; namely that games are laborious and resource intensive to use, and that there are few standards established to guide educators through the complex process of integrating games into their working environments. The paper specifically focuses on examining the roles that teachers need to take on when implementing and using computer games in their classroom activities. This is achieved through the execution of two case studies conducted during two five month long projects where the researchers collaborated with K-12 teachers to integrate a commercially available educational game intended for classroom use, MinecraftEdu, into their curriculum. It is important to highlight that the paper does not discuss the educational effectiveness of the used game. Instead it focuses on examining the tasks and roles that teachers need to take on when they include game-based activities as a fundamental part of a curriculum. This includes the more practical tasks that are necessary when teachers establish a “game-ready” classroom environment in which gaming activities can take place, but also the ones involved in supervising and guiding a class of students as they engage with a school subject through game play.

2 Method

This research employs case studies to examine the processes teachers need to go through when implementing and using digital educational games in their working environments. The primary methods used during the case studies conducted for this research have been participatory observation protocols, transcriptions of classroom gaming sessions, and interviews with teachers.

2.1 Case study designs

This paper takes the stance that examinations of games’ actual usefulness and viability as educational tools requires empirical real-world studies on the actors that are to utilize them and the systems in which they are to be used. To that aim, this research employs case studies to examine the processes teachers need to go through when implementing and using digital educational games in their working environments. Case studies are, according to Yin (1984) “... preferred when studying contemporary events, but when the relevant behaviors cannot be manipulated.” That is to say, case studies are potent when it comes to describing not fully fleshed out phenomena in their real-life context. Yin further points out organizations and processes, and the way interventions are implemented and impact them especially ripe targets for case study research (1984, p.19-25). It is primarily due to these traits of case studies that we deemed them appropriate to examine the complex, and in many ways little understood, processes that are involved in the implementation and use of games in formal educational settings. This section will provide the broad outline of the research context and the employed methodologies, but a more comprehensive account can also be found in (Berg Marklund, 2015).

The methods were employed during two five-month long instances of educational games use in a Swedish K-12 environment. During the case studies, one researcher collaborated with three different teachers, one teacher working with a class of 7th graders and two working with a class of 5th graders, throughout a game-based learning project. The projects entailed initial discussions of educational goals and how games related to them, acquiring game software and implementing it in the classroom environments, and orchestrating gaming sessions. The first projects meetings were conducted in November 2014 and concluded in March 2015, where the initial month was spent on preparatory discussions and hardware and software preparations, and the remainder was spent on conducting weekly classroom gaming activities. During each of these activities, the researcher kept a protocol of observations, and interviews as well as classroom gaming sessions were recorded and transcribed. After the game-based curricula had been concluded, follow-up interviews were held with the involved teachers to debrief and summarize their experiences.
The two different cases constitute two different types of classroom setups. The students in the 7th grade were all part of a national program that supplied them with one laptop per individual, whereas the 5th graders had a limited number of computers to share within their class. The classroom sessions were thus structured differently, as the older students had enough hardware to play games as a whole class (all 24 students could play simultaneously), and the younger students played in smaller groups (dividing 24 students into two groups of 12, that shared six computers). Figure 1 shows the different classroom setups.

![Figure 1](image1.png)

**Figure 1**: Though the 7th grade students (left) owned one laptop each, they were divided into groups of two and shared one laptop. The 5th grade students (right) worked in groups of two on communal laptops.

The two different classes also worked within different subject matters, as the 7th grade class worked with mathematics and geometry, and the 5th grade class worked with medieval history. This informed the structure of the activities the two classes participated in. The purpose of the game-based learning activities with the 7th graders was to let them experiment with length, area, and volumetric scaling in a three-dimensional environment. For the 5th graders, the game-based activities revolved around the research, re-creation, and re-enactment of iconic structures and communities from a specific historical time period (the Middle Ages). As such, the mathematical gaming curriculum focused on heightening students’ understanding of geometrical objects and calculations by letting them manipulate and construct those objects first-hand, and the historical curriculum focused on letting students experience and reflect on the taught subject matter through re-creation and re-enactment. Figure 2 shows a snapshot of how these lessons were manifested in the game environment.

![Figure 2](image2.png)

**Figure 2**: In the history curriculum (left), the students built iconic structures and rudimentary societies from the Medieval Ages (like a monastery and adjoining farms, as pictured). In the mathematics curriculum (right), the students calculated scale ratios, drew blueprints, and built simple geometric objects and scale models of real-world objects (like the large die on the right side).

The authors would like to emphasize the thoroughly collaborative nature of these game-based learning projects. The field researcher did not passively observe the projects as they unfolded, and played an important part in their execution at several junctures. However, this paper argues that the interventions made by the researcher are interventions that any teacher would need to make in order to integrate games into their classroom environment as well. All interventions were discussed with teachers before they were made, and the interventions served project goals established by the teachers. Since they are likely to be necessary steps in any game-based learning project, the tasks performed by the researcher will thus be analyzed as teacher tasks. The outcomes of the studies will be presented below, and examples of the different challenges the teachers and researcher faced, and the roles they needed to take on during the game-based learning projects, are coupled with excerpts from transcripts and observation protocols.
2.2 Data collection and analysis

During the study, a total of classroom sessions 17 game-based classroom exercises were executed; 8 with the 5\textsuperscript{th} grade class, and 9 with the 7\textsuperscript{th} grade class. All but the initial classroom activities were recorded through the use of three voice recorders placed throughout the classrooms. The most extensive data set for the studies were the transcriptions made from these recordings.

After a classroom exercise had been conducted and recorded, the audio was uploaded to software in which the three different recordings could be synchronized to allow for easier manipulation (e.g. muting tracks of the recordings to focus on specific discussions). To make the transcription process more manageable, a transcription protocol was established. According to the protocol, transcriptions were to begin with the first 10 minutes of exercises, and would be followed with subsequent transcriptions that were based on the ‘points of interests’ identified in the participant observation protocol.

The reasoning behind the simplification of the transcription process was that the first 10 minutes often contained the widest variety of activities throughout the classroom. During the first 10 minutes, the teachers and the researcher would make many different types of interventions to assist students in starting the game and in planning their execution of the exercise. Furthermore, the first few minutes would often contain most of the technical difficulties that the teachers would need to resolve. Finally, the general classroom atmosphere and tone of student collaborations would often be established within the first ten minutes as well, which was helpful for contextualizing discussions during the points of interest found in the observation protocols.

When the transcripts of all the exercises were completed, they were collated and subject to thematic analysis, according to guidelines provided in Braun and Clarke (2006). After the researchers had familiarized themselves with the transcribed data, discussions and student behaviors were coded into broader categories (e.g. excitement, frustration, subject matter discussion, game mechanic discussions, etc.). After a first round of coding, the data set was revisited, and the codes were collated into themes – which was ultimately used to choose excerpts that exemplified certain types of behaviors of relevance to the research question.

3 Results

In this section, the different roles that the teachers had to manage during two core ‘phases’ of the game-based learning projects will be presented. The first phase covers the process of integrating the game into the educational setting, and the second phase covers what the process of using the game as a classroom activity entails.

3.1 The conditions of formal education, and their impact on game-based learning processes

An essential step teachers need to take before embarking on any game-based learning project is to assess what they might be able to do given the conditions they are working under. Any formal educational environment consists of elements that can either facilitate or complicate game-based learning processes. In the initial stages of the two case studies, teachers and researchers discussed some of the conditions that were likely to complicate their work, as well as the resources and structures available in their environments that could be valuable assets.

3.1.1 Designing the game-based curriculum

One of the more pressing questions that an educator needs to ask in the initial stages of a game-based learning project is what kinds of gaming sessions their schedule and curriculum allows for. In the studied cases, the curriculum demands and the availability of hardware informed both the choice of game and the plans of how gaming sessions were to be scheduled and conducted. In the class of 7\textsuperscript{th} graders, the abundance of laptops, short classroom periods (45-60 minutes), and the stricter demands and educational goals established in the curriculum made the teacher gravitate towards shorter stand-alone sessions. In the stand-alone session setup, students collaborated in groups of two or played individually on assignments with fixed starting- and end points, which allowed for easier assessments of students’ progress. Viewing each classroom session as a stand-alone exercise also had the benefit of allowing for changes in the design of the game assignments according to the rate at which the students mastered both gameplay and details of the taught subject matter. The conditions were quite different in the 5\textsuperscript{th} grade class where the period times were longer (90 minutes), the curriculum goals were less strict, but there was significantly less hardware available. For the
younger class, a more long-form collaborative classroom exercise was chosen. Figure 3 shows the basic differences in project structures between the two working processes.

![Figure 3: Overviews of the game-based learning projects. The long-form project spanned several weeks of gaming sessions, and more work was done before and after the project to contextualize game content in the subject matter. The stand-alone sessions were more beholden to curriculum demands, and was characterized by smaller assignments, progressively increasing challenge, and continuous assessments.](image)

The constraints imposed by curriculum demands and scheduling also play a deciding role when it comes to choosing the type of game to work with. In the studied cases, *MinecraftEdu* was chosen due to its modular nature and accessibility; the game’s focus on emergent ‘sandbox’ play makes it possible for teachers to model gaming challenges after their own educational goals and working conditions (i.e. the game is easily customizable); it runs adequately even on older computers; and it is a title many students are familiar with, thus lowering the barrier to entry for many students. These benefits outweighed the potential drawbacks of the game, such as its low physical, functional, and visual fidelity. For example, it is difficult to create spherical objects in the game (due to its blocky nature), and objects sometimes have little visual resemblance to their real-world counterparts. However, while these types of drawbacks presented some challenges, they were not a major source of concern for the teachers.

3.1.2 Establishing the infrastructure to enable gaming sessions

When it came to integrating the game into the classrooms, the primary concerns for both cases were: the uncertainty of hardware reliability; the teachers’ self-admitted low gaming- and technology literacy; and the limited amount of working hours they could feasibly spend on preparing for classroom gaming sessions. In the cases studied, the low game- and technology literacy of the teachers would make it highly unfeasible to start any type of game-based learning if it were not for a couple of ameliorating circumstances: the presence of the researcher, and the teachers’ students themselves as both classes had several students who were very proficient with both computers and the used game. The process of game integration thus relied primarily on the researcher, and when the researcher was not present the teachers could get some assistance from the more technology proficient students in the classes.

Establishing an infrastructure that supports gaming involves taking inventory of the resources currently available in the environment and organization, procuring resources that are currently lacking, and making sure that the needed software and hardware is available and prepared for gaming sessions (these steps are outlined below, in Table 1). The details of this process are likely to differ between schools and classrooms since organizational support structures, technological infrastructures, and teachers’ technology literacy is different for each individual case. However, comparing the statements from teachers and observations from this study to previous research indicates that these unfavourable conditions for game-based learning are not uncommon (Egenfeldt-Nielsen, 2008; Linehan et al., 2011; Wastiau, Kearney & Van de Bergh, 2009). Thus, establishing a solid infrastructure that allows for reliable and efficient gaming sessions is likely a task that is not specific to the cases studied here, and it is a task that should not be underestimated as it requires significant investments in resources and effort.
3.1.3 Administrative tasks during and around gaming sessions

An inescapable and integral part of using games for educational purposes is the continuous management of the tools that make gaming sessions possible. Computer games are complex pieces of software that require advanced hardware to function reliably and efficiently. Setting up and orchestrating these components in a classroom environment, even for rudimentary game-based learning activities, constitutes a significant time investment and requires a high level of technological proficiency.

Since the characteristics of the two studied cases differed in many ways, the administrative efforts needed to set up and conduct gaming sessions were different. However, while the specific details of the process differed between the cases, there are definite phases that both needed to go through: taking inventory of their current educational environment and processes, implementing the chosen game into their environment, and conducting maintenance between and during gaming sessions. Each of these phases consisted of several smaller activities. The necessity of performing the individual activities varied between cases as a result of the classroom setups and the availability of hardware, as shown in Table 1.

Table 1: A summary of the steps involved in the three different phases of integrating and using game technology into an educational environment. Some steps were not applicable to both cases (the X marks whether a step were necessary in the corresponding case)

<table>
<thead>
<tr>
<th>Activities</th>
<th>7th grade classroom</th>
<th>5th grade classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take inventory of available hardware/resources</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Evaluate student profiles</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Examine curriculum goals</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Examine game software</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Establish educational goals for the game-based project</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pull in organisational support structures</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare the technology infrastructure</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Purchase game licenses</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Installation of software</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Prepare the classroom environments</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Prepare the game environments</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Setting up game servers</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Preparing in-game subject matter content</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Saving games and managing backups</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tech-support during game sessions</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Closing down lessons</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hardware maintenance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Patching and software maintenance</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

To provide a few concrete examples of how steps differed between the two cases, the stand-alone exercise design chosen by the 7th grade teacher alleviated the need to prepare the game environments students played in. As the students in those classes also worked on their own computers, the classroom and hardware did not need any notable preparation before game exercises, nor was setting up servers or saving and keeping backups of game data necessary. However, due to the higher amount of computers, the process of installing the game software was longer, more intricate, and more prone to errors. As the stand-alone sessions followed a steady progression of challenges, the classes required preparations of in-game examples of different mathematical expressions in Minecraft. That was not necessary in the 5th grade class, since they worked on a long-form creative exercise where students mainly followed their own building plans.

3.2 Conducting classroom sessions

Once the foundation for game-based classroom activities have been built, the teachers can start becoming more focused on conducting said activities. During the case studies, it quickly became apparent that classroom gaming requires the teacher to be versatile as they both need to carry out the necessary preparations before gaming sessions, but also act as game administrators during them. In this section, some of the more common challenges that teachers faced in during the classroom exercises will be presented through the use of excerpts from researcher and teacher observations, as well as student discussions and behaviours, that encapsulate how these different challenges arose during the game-based exercises will be provided.
3.2.1 Managing the diverse preferences and proficiencies among students

The classes of students proved to be highly heterogeneous when it came to their gaming proficiencies and preferences, and these differences often caused problems when it came to students’ collaborative behaviours. Tutoring novice students in how to play the game, as well as the proficient students in directing their gaming expertise towards solving assignments, was arguably the most time-consuming responsibility for the teachers during the game-based exercises.

The heterogeneity of a K-12 classroom as a gaming audience cannot be understated. Each individual student has their own levels of gaming literacy, gaming preferences, subject matter knowledge, motor skills, motivations to play and learn, socio-economical background, and general interests. In both of the studied cases, a large portion of the teachers’ and researcher’s classroom interventions consisted of helping students launch the game, and subsequently to understand the basic interface and concepts of Minecraft. As an example, in an observation protocol from a gaming session with the 7th grade class on the 22nd of January, the researcher described their role the following way: “A lot of students (around a fourth of the class) still don’t know how to start the game or how to play, how to interpret ‘blocks’ as units of measurement, how to choose and place blocks in the game interface, or even how to steer their avatar (the combination of WASD steering and mouse movement is difficult for many), I spend a lot of time running around and managing these issues.”

In this example, some students had problems launching their game and navigating a game interface that some might consider self-evident. Building on this, the collection of transcript excerpts below show how severely students’ grasp and approach to the game can vary in a single class during the same gaming session (translated from Swedish, all students are given pseudonyms to ensure anonymity):

Excerpts from a 7th grade exercise on February 27th

Beatris: [To researcher] You have to help me! I don’t know where I need to go [to start the game]… is it this one?
Peter: [To classmate] What program are you using? WorldEdit?
Wallace: It’s spelled “WorldEdit” (the name of a popular Minecraft modification). But you have to know… you have to write it into google.
Wallace: You can check out tutorials on YouTube on how to install it.
Peter: Alright, WorldEdit. Here it is.
[A few minutes later, Peter still did not manage to get the modification to work]
Wallace: Go back *mouse clicks*… Yeah, you need to put it in the ‘Versions’ folder if you want it to work. You need to put it in ‘Versions’.
[Rose is building a cube in Minecraft, and is placing blocks down – she encounters some issues when she needs to erase blocks that she misplaced]
Rose: I’m getting pretty good at this!
Rose: Wait, I forgot how to do this…
[–]
Rose: This is the second time I’m playing Minecraft!

The heterogeneity of K-12 students can make classroom sessions difficult to design and monitor as the students who have never played a computer game before needs to be able to collaborate and communicate with students who are very proficient players. As the excerpt shows, students’ proficiency in using technology and playing games can differ severely in a classroom. While some students are struggling with the basic interface, others are advanced enough to complain about hardware performance, or will start to modify the game in order to elevate their gameplay further since the basic game is not engaging enough.

As might be expected, the gap between individual students’ gaming proficiency varied the most during the earlier game-based exercises. As the game-based curricula progressed, and novice students were tutored in the basics of the educational game’s interface, the proficiency gap lessened, and a wider range of students were able to participate more effectively and autonomously in the exercises. The being said, the proficiency gap never shrunk to the degree where it didn’t noticeable affect the way the students collaborated and played together, and game tutoring remained a time consuming task for the teachers even towards the very end of the curricula.

The proficiency gap would sometimes cause or exacerbate unproductive or exclusionary patterns of collaboration in the student cohorts. In the examples below, for example, proficient students were noticeably nonchalant or dismissive towards their less proficient classmates’ wishes to engage with the game or the class assignment:
As such, the novice students’ were not the only ones that required guidance during the game-based curricula, as more proficient players also frequently needed to be guided towards more productive collaborations with their classmates. Similar observations have been made by previous scholars as well. Frank (2012), for example, has shown that proficient players can become overly focused on self-actualization through mastery of game mechanics or achievement of game goals, to the exclusion of engaging with the subject matter that the game is intended to represent. Frank (2012) dubbed this type of behavior during game-based exercises as ‘gamer mode’, and state that it can be detrimental to collaboration as well as learning, as players start focusing on exploiting and manipulating game mechanics instead of focusing on the subject matter details that the game is intended to convey. A constructive and focused student-to-student discourse is reliant on the gaming activity remaining ‘framed’ as an educational activity that students partake in by playing with a reflexive and analytical mind-set. During both studied cases, student groups frequently became unfocused when the act of gameplay separated itself from the educational goals of the classroom sessions. After a classroom activity on the 20th of March, the 7th grade teacher reported that: “Sometimes the game is more enticing than working and focusing on the assignment. For example, a friend might look for facts about the [subject matter topic], so meanwhile [the other student] can play around freely in the Minecraft world.” These behaviors emerged quite frequently in the transcripts as well:

Excerpt from a 7th grade exercise on February 27th:

I’m going to do an awesome thing.

*Silence, with lots of mouse-clicks in the background*

Teacher! Can we get some help?

*Pause, the teacher comes over*

What do you mean by “Settle on a scale”? (She is referring to a part of the assignment, where the students need to decide what scale their model of the real-world object will be in)

Have you decided how to scale the object you’re building?

Yes.

Have you decided how ‘large’ your blocks are [in Minecraft]?

... No.

You need to decide the measurements of your blocks.

Oh, how large they’re going to be?

[From this point, James joins the teacher and Anna in the discussion of the assignment, and they start planning how to conduct the exercise together.]

In situations such as these, the teacher’s presence seemed to help reinforce the educational framing of the gaming activity. There are several other examples in the transcripts of the teacher being called upon to mediate these situations. In many of the examples, the teacher is utilized by some students as a ‘technique’ to get their more game-focused working partners to focus on the class assignment. These situations most frequently occurred in groupings where students with clear “gamer” personalities were matched with less
game-proficient students. As a final example of how these mismatches could affect students’ collaborations, the below excerpt shows how students’ opinions of game objects’ appropriate use could differ:

Excerpt from a 5th grade classroom exercise on February 17th

[Felicia and Miley are building a storage room and Miley is stacking chests on top of each other to fill the room with storage compartments. Felicia is an inexperienced player while Miley is very adept with the game. Felicia is commenting on how illogical it is to stack chests on top of each other – realistically, it would be impossible to open the lid of the bottom chest if another object sits right on top of it.]

Felicia: I don’t think they had... um. Chests like that.

*Pause*

Felicia: I don’t think they had the technology to do things like that.

Miley: Whaat?

Felicia: I don’t quite think that they had that technology – like, how are you going to open them?

Miley: *Unintelligible retort*

Felicia: *Laughs* ... the one that’s on the bottom?

Miley: *In a silly voice* Felicia you can build like that in minecrapaaaaoaft

Felicia: *Giggles* But if you put a thing down, super close to the other thing that can be opened. why... [Miley interrupts]

Miley: Oh come on, it- it- it’s lagging!

Felicia: ... can you open it? [Felicia finishes her sentence]

Miley: Like it- it- it double-clicks when you only click once...

Felicia: Shouldn’t we also put in a monastery citizen? [Felicia keeps talking parallel to Miley]

Miley: ... sometimes!

In this example, Miley and Felicia are of different opinions when it comes to how game objects should be used. Miley, the more proficient player, operates within the bounds of “game logic”, which in this case clashes with the reality that they are assigned to represent. Felicia, the less proficient student, objects to the unrealistic use of the chests. This is swiftly followed up by Miley turning her focus to the performance of the hardware, while Felicia tries to keep the discussion focused on the assignment. In summary, the mismatches between students’ gaming proficiencies gave rise to two challenges that teachers needed to be able to supervise and negotiate; the one of exclusionary and controlling student behaviours (i.e. a proficient player starts to exercise control over a situation and other players, thus limiting other players’ ability to engage with the game content), and the one of students entering ‘gamer mode’.

3.2.2 Contextualising game content in the taught subject matter

Miley’s and Felicia’s interactions also relate to a second challenge involved in conducting game-based classroom activities: encouraging students to keep the taught subject matter in mind when choosing how to interact with, and interpret, game content. One commonly recurring challenge the teacher tackled during gaming sessions was to bridge the gap between the game content and the details of the subject matter the game is intended to teach. By necessity, games often make compromises in physical-, task-, and functional fidelity (Liu, Macchiarella & Vincenzi, 2009). Games rely a lot on abstractions and representations, and players continuously interpret or ‘translate’ game objects and actions to real-world objects and actions – if the game action is very dissimilar to the real-world action, there is always a risk that things get lost in translation. If a game is not specifically designed to teach the details of the subject matter with a high level of authenticity and fidelity, the task falls on the teacher to draw connections between the game content and the subject matter (Alklind Taylor & Backlund, 2012).

To briefly summarise the difference between proficient and novice players when it came to interpretation, proficient players could think of game content (e.g. aesthetics and functionalities of game objects and different types of game mechanics) in figurative terms, whereas novice players tended to interpret them very literally. The proficient players’ processes of interpreting game content were, for lack of a better word, ‘fluid’. Depending on the situation and the context, game objects could simply be viewed according to all their immediate properties, with both their aesthetics and functionality treated as they were given in the game. They could also solely be interpreted according either exclusively based on their functionality or exclusively on their aesthetics. When working with complex themes and concepts (e.g. history, social sciences, ecology, biology, etc.) in games, students need to collectively ‘pretend’ that certain objects should be interpreted and used a certain way. For example, the students in the 5th grade class used “Spider Webs” as puffs of smoke due to their visual similarity to tiny white clouds, even though the mechanics of the object share no similarities to smoke. Conversely, students sometimes disregarded an object’s visuals if the functionality it represented was in line with what they aimed to convey. For example, students relied on the “Chest” object as a universal
symbol for ‘storage’, and used it as such even when its visuals clashed with the setting. Some students are very adept at negotiating what qualities of objects they should ‘see’ and which ones they should disregard, but just as is the case with gaming proficiency – this skill varies radically between individual students.

Novice players often displayed less fluidity when it came to interpretation, which significantly limited the ways in which they chose to interact and engage with the game mechanics. If game objects did not accurately represent the looks and function of its real-world counterpart, novice students would have a difficult time using them at all – this often led to frustration and disappointment as the students felt like their tools of representing what they wanted to were very limited. The low-fidelity nature of Minecraft, both in terms of visuals and object functions, may have exacerbated these issues during these studies, and disconnects between game objects and the real-world objects they were meant to represent occurred rather frequently. The modes of interaction presented by the game are very rudimentary, and the objects the players interact with are also visually and functionally minimalistic. The below transcript excerpt contains a situation in which students have trouble seeing past small disconnects between game content and the subject matter:

Excerpts from 5th graders’ exercises on February 3rd
[Louise and Julie, two novice players, have finished the foundation of their building (a sleeping cabin), and are looking for ways to decorate it further]
Louise: Maybe there should be bookshelves, then? That’s...
Julie: Did they have those back then?
Louise: What?
Julie: Did they have those?
Julie: Yeeees. They had a tonne of bookshelves.
[... the students discuss placement for a few seconds, until they finally start placing bookshelves in the game world]
Louise: If it looks too colourful we’ll remove it.
Julie: Should we put it on this side?
*Pause, mouse-clicks are heard*
Julie: Okay, so umm *laughs*... this is, like...
Louise: Looks a bit colourful.
Julie: Yeah.
*Pause*
Julie: Let’s remove them.
Julie: Yeah.
[... the teacher comes over]
Teacher: Why did you remove [the bookshelf]?
Louise: Because it looks a bit weird.

In this example, the visual representation of bookshelves in the game (being slightly modern) clashes with the subject matter (medieval history). This can be viewed as an example of limited physical fidelity being troublesome to negotiate and challenging the collective act of ‘pretending’. These issues were also sometimes quite persistent, and some students could have a really difficult time developing the gaming literacy needed to start treating game objects like representations or abstractions. Louise and Julie’s issue with the bookshelves, for example, persisted across several game-based classroom exercises:

Excerpt from 5th grade exercise, 2nd of March
[Louise and Julie are revisiting the subject of bookshelves and decoration for their sleeping cabin]
Louise and Julie: *Unintelligible* but, nooo, what...
Louise: It’s just so darn boring.
[The teacher hears the students and walks over from the other side of the room]
Teacher: What’s boring, Louise?
Louise: Um, Umm. A little... *unintelligible*
Teacher: Like, it’s like *unintelligible* when we are trying to spruce it up a bit.
Teacher: Alright, how are you visualising it?
Louise: Like bookshelves, but they must be... they are just so darn big.

Even after having dealt with the issue of “sprucing up” the sleeping cabin they were building for a month, the students were still unable to get past the small incongruities that they saw between the game objects and the real-world objects they were meant to represent.

These examples from the 5th graders’ gaming sessions, where they worked with recreations of historical buildings and societies, are but a few of many. As previously described, the simplistic nature of Minecraft objects’ aesthetics and functionality meant that game content often failed to correspond well with the subject
matter details they were intended to represent. These clashes sometimes challenged the collective act of ‘pretending’, but could be negotiated among students or with the help of the teacher. The teacher’s task in these situations is to maintain the established ‘contract’ that state that the fiction of the subject matter is to be maintained, even when the game itself does not enforce it in any way or even tempts students to break it. The below excerpt exemplifies that type of subject matter-centric behaviour, and how students could collaborate to maintain the authenticity of the subject matter they were recreating in the game:

Excerpt from a 5th grade classroom gaming exercise on February 24th

[During an exercise, Dan is working on a stable for a farmhouse near the group’s monastery. A couple of other students, Peter and Adam, note that Dan is filling the stables up with horses]

Peter: Dan, the horses were super expensive.
Teacher: Expensive?
Dan: Yeah...
Adam: Yeah, and we have a whole bunch of horses.
Peter: Don’t you remember that, Dan?
Adam: We have them in the stables too.
Peter: They cost like 200 pigs or something like that.
Adam: Or five cows.
Teacher: Yes, they were really expensive.
Adam: Yes, it was probably more common to have like three or four horses.

In this example, horses are functionally infinite and the students could easily place several dozens of them in their medieval monastery. But by discussing the subject matter, the students started imposing their own constraints based on their interpretation of how game objects corresponds to the subject matter. The above example occurred towards the end of the game-based curriculum, and it took several exercises for the teachers to cultivate the educational framing necessary for students to start collectively contextualizing the game objects in the taught subject matter on their own.

3.3 Summarizing remarks on conducting a game-based curriculum

At the end of the five-month game based curricula, concluding interviews were held with the involved teachers where the outcomes and their experiences of the projects were discussed. Although the interviews focused on many different aspects of the conducted game-based curricula, two key points were brought up by the teachers that well encapsulate the challenges that the teachers and researcher went through during their five-month long collaboration; the challenges involved in ensuring that game-based exercises remained focused on the taught subject matters, and the challenges of establishing and maintaining a sound technological infrastructure in which gaming sessions could be reliably conducted.

The 7th grade and 5th grade teachers all stated that they had experienced some difficulties when it came to making sure that the students participated in the game-based exercises with the taught subject matter in mind. Here, the teachers noted that there was a conflict between how the students were used to playing games at home, and how they were “supposed” to play it during classroom hours. Although this conflict could be difficult to manage, as evident by the numerous instances of students being distracted by game elements irrelevant to the taught subject matter found in transcripts and observation protocols, the researcher and the teachers had found some ways in which to alleviate its effects. One way was to make the classroom gaming experience as different from the students’ own gaming habits as possible, for example by disabling some game features (e.g. the monsters in the game), or enabling others. In an interview held after their game-based curriculum had concluded, one of the 5th grade teachers noted that: “I think, just as you have switched [some game components] off, there needs to be a focus on [the school subject]... Because, when they play on their own, a part of the whole thing, a part of the whole game is to survive, or avoid zombies coming to get you, or something else. But now we didn’t have that, because now ‘it was school’, kind of. Because you need to feel that difference, that ‘now the focus is on [school, and not the game]’.” In essence, clearly demarcating that the gaming sessions held in the classrooms were different from the ones students had at home was an important part in establishing an educational “framing” for the exercises. This was done both by ensuring that the game sessions and the game components were clearly contextualized within the broader curriculum goals, and by ensuring that the game itself was different from the one the students played at home.

The second important takeaway from the concluding interviews with teachers were their perspectives on how feasible the use of educational games was in their day-to-day work. The teachers all clearly stated that it
would not have been possible to conduct the game-based curricula without the support of the researchers. The teacher of the 7th grade class, for example, stated that the issue both related to technological aspects of game-based learning and his own ability to work with game environments, and implementing and using educational games were, even after the five-month long collaboration, seen as unattainable without outside support:

Excerpt from post-curriculum interview with 7th grade teacher:

Researcher: Now that we’ve concluded the curriculum. Does it feel as if… do you feel as though you could have conducted this work on your own?
7th grade teacher: No. No, I could not have sorted it out.

Researcher: So do you feel as if you would be able to work with games now, after the project?
7th grade teacher: No. No. *laughs* No no.

The teachers’ overall experience was that games were too labor intensive, and too unreliable, to be made an integral part of their working processes. Without the extensive involvement of a third party (which in this case was the assisting researcher), the teachers would not have had the resources to be able to establish the technological infrastructure required to make gaming sessions possible. Without a solid foundation of well maintenance technology, games can quickly become unruly to use, and technical difficulties can quickly start piling up. Since classroom hours are finite and highly valuable, a teaching tool that requires a lot of preparation only to ensure that it functions reliably for each classroom session is rather risky, and planning an entire curriculum around it even more so.

4 Conclusion and discussion

By collaborating with teachers during a game-based learning project, this research revealed that teachers need to take on a wide variety of important roles when integrating and using games in their educational environment. The skill sets needed to perform the roles well were also found to be quite diverse as they involved technological know-how, gaming literacy, subject matter expertise, and naturally a strong pedagogical foundation.

At the outset of a game-based learning project, the teacher needs to be able to review the conditions of their educational environment. Organizational support structures, availability of hardware and software, and the availability of other resources or obstacles, need to be considered before the game-based learning curriculum is designed. Basic practicalities like class schedules, educational goals as stated by national curricula, and technological infrastructure all inform what type of game can (or should) be used, as well as the design of gaming sessions and assignments. These findings, in contrast to the ones made by Chee, Mehotra and Ong (2014) whom suggests that “the key challenges teachers face are not technology centric but practice centric” (p. 313), identify technology availability and literacy as a major bottleneck and guiding factor in the integration of digital game-based learning in schools. A fundamental issue with game-based learning in formal education is that games, in their current state, are not particularly reliable as teaching tools. Establishing a technological infrastructure in which digital games can function reliably and efficiently, and conducting regular maintenance to ensure that they keep doing so for every classroom activity, requires large time and resource investments. The schools involved in the case studies presented in these papers were, comparatively speaking, fairly well structured in terms of available technology and organisational structures and resources – but even so, the use of the educational games were wholly dependent on the authors’ involvement and support.

When actually conducting the classroom gaming sessions, the teachers need to take on an additional set of roles. During a typical gaming session, teachers need to act as game administrators, lecturers, game tutors, subject matter anchors, and authority figures that keep students in an educational mode of play. In a big classroom, it can be difficult for teachers with low gaming literacy to spot situations where novice students are struggling with the game interface, or when students are not working towards educational goals. However, being game literate does not necessarily entail game mastery, but rather that the teacher can understand gaming and game content in order to make use of it. As put by Bourgonjon and Hanghøj (2011), “teachers don’t necessarily need to become experts with every new medium, but at the very least need to know what is going on [...] in order to participate” (p. 71). Gaming literacy was thus not only important for monitoring gaming sessions, but also for the teacher to be able to plan and conduct contextualising activities surrounding their gaming sessions. For example, the 5th grade teachers introduced the students to the medieval history
concepts they were going to be working on in Minecraft long before the gaming sessions started. After the gaming project was over, the teachers also pulled aspects of the buildings and societies the students had created into other school-work. Although these surrounding exercises were not highlighted in this research, they played an important role in exploring more intricate details of the subject matters. Constructive learning situations arose occasionally during gameplay as well, but the surrounding exercises provided the necessary contextual knowledge that allowed such situations to occur. The gameplay itself did not have much intrinsic educational value, but when it was contextualized appropriately and executed purposefully, it played an interesting and valuable part of larger learning processes.

On the topic of gaming literacy, the conducted case studies also clearly showed that individual proclivities, skills, and preferences vary dramatically even among students who are of similar ages and backgrounds. This is an indicator that the notion of ‘digital nativity’ (Prensky, 2001), which is still treated as a truism by many practitioners and scholars in the field of game-based learning (e.g. Annetta, 2010; Malliarakis et al., 2015; Vanderhoven et al., 2015) despite being discredited by many researchers (c.f. Guthrie, 2014; Jones et al., 2010), is deeply flawed. The concept of digital natives is detrimental to the discourse of educational games, as it is a way of consolidating individuals with varying needs and backgrounds into a more easily managed monolithic entity, the description of which only applies to persons of very specific proclivities and favourable socioeconomic standing where technologies and games are easily available. Of the students observed during these studies, only a relatively small segment of students were able to navigate computers and the used educational game with high proficiency, and many students needed tutoring in some very basic tenets of computers and games to be able to participate in the exercises. Digital nativity sweeps the complex diversity of today's students under the rug, and developers who design games with digital natives in mind are at risk of producing educational products that may work well for the subset of students that have the characteristics of a 'digital native', but excludes the ones that do not.

The studies presented in this paper showed the many processes and tasks involved in creating and designing a game-based curriculum, as well as implementing and using educational game software in a classroom setting. Game-based learning places a lot of demands on teachers and requires them to take on many different roles, each of which requires a specific skillset. Integrating games into formal educational settings is a laborious and complex process, and as indicated by the teachers that participated in these studies it involves too heavy investments in resources and time to be considered a feasible part of their working processes. This is partly due to the fact that schools are not structured for game-based learning, but it is also due to games not being sufficiently accommodating for the needs of teachers or the many characteristics an educational context may have. For game-based learning to move forward, teachers need to have a better understanding of games and how to work with them, and game creators need to understand teachers' working conditions and know how to accommodate for the varying characteristics of formal educational settings with their products.

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E-Learning Sudan, Formal Learning for Out-of-School Children

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Abstract: E-Learning Sudan (ELS) is a custom-built computer/tablet game that provides alternative learning opportunities to Sudanese children who are excluded from education. Unique in ELS is that children can learn mathematics, in their own remote village, without a teacher. This research study assessed the effectiveness of ELS in two pilots through a pretest–posttest control group quasi-experimental design. In Pilot I, 67 children in three remote villages, used the game for a period of six weeks, five days a week, 45 minutes a day; the control group did not receive any education. In Pilot II, 591 children in 19 remote villages, played the game for six months, for a maximum of five times a week, 45 minutes a day; the control group received informal education in out-of-school centers. The results of the analysis on the pretest–posttest data revealed that ELS increased mathematics knowledge acquisition in numeracy and adding significantly and maintained student motivation to learn. Analyses of control group data and EGMA (internationally validated Early Grade Mathematics Assessment) showed that the children in the experimental group learned more than children who received no education at all, informal or formal education. These findings suggest that the implementation of ELS can greatly benefit learning for out-of-school children like in Sudan.

Keywords: game-based learning, autonomous learning, primary education, mathematics, developing countries, evaluation

1 Introduction

As other Sub-Saharan countries, Sudan struggles with issues regarding access to education and educational quality (Mtika 2010; The World Bank 2012). The push to achieve the goal of educating every child at least to primary level (enshrined in the Millennium Development Goals and now the Sustainable Development Goals) puts pressure on educational systems which already struggled to cope with demand. Although the push towards universal access has substantially increased education enrollment, reaching those without access to school is a pressing issue, particularly girls and children in the rural areas in Africa and South Asia (Kallaway 2001; Cremin 2012). Equity still remains a major issue, not only involving girls, but also the poor, including linguistic and ethnic minorities, and other disadvantaged groups (The World Bank 2012; Kallaway 2001).

There are approximately 2.3 million children in Sudan not in school. At present, it is not realistic to believe that this will be solved through traditional means (schools and teachers). Due to the cultural, geographic and socio-economic background of children, more flexible, empowering and affordable approaches outside formal schools are required. The focus of this approach should be on rural areas, communities affected by conflict — including Internally Displaced Persons (IDPs)- and specifically include girls and minority groups. Online and distance learning with ICT are seen as possible solutions. Digital technologies, if the software is well-designed and the content grounded in a well-constructed curriculum, can deliver one-to-one interactive instruction, in a consistent manner, to all children. Children can learn at their own pace and repeat material as often as they need. The use of technology also allows for the individual monitoring of progress.

Promoting understanding of mathematics in the early years is critical, as longitudinal research has shown that early mathematical understanding is highly influential on later mathematics and reading performance at school (Duncan 2007), even after controlling for other basic skills that are known to affect school performance.
This study reports the results of two pilots in which a gamified version of the Sudanese curriculum for mathematics for out-of-school children was tested. The mathematics curriculum comprises the learning goals for Grades 1, 2, and 3 and leads to an official certification (Stubbé in press).

Because this way of learning is completely different from the formal school system in Sudan a proof of concept was needed before the three-year curriculum could be developed into a game. The most important question that needed to be answered was if children can learn mathematics by playing the game. Following the ‘fastest route to failure’, a small part of the game (Pilot I: six weeks of the curriculum; Pilot II: six months of the curriculum) was developed and tested in remote communities in three states in Sudan.

Various meta-reviews and meta-analyses have shown the cognitive and motivational effects of serious games in general. In their meta-analysis of 32 studies in which traditional classroom teaching to computer gaming or interactive simulation were compared, Vogel et al. (2006) found an overall positive effect of serious games: significant higher cognitive gains and a more positive attitude towards learning were observed in subjects using interactive simulations or games versus traditional teaching methods. This seems to be the case for boys as well as girls, although the low number of studies that reported statistics for males and females gives reason to consider these results with caution. All age groups showed significant positive results for the use of computer gaming or interactive simulation. The type of activity did not appear to be influential; neither did realism of the pictures in the game. Wouters et al. (2013) investigated whether serious games are more effective in terms of learning and more motivating than conventional instruction methods. In their meta-analysis of 39 studies they found that serious games were more effective in terms of learning and retention, but were not more motivating than conventional instruction methods. Learners in serious games learned more than those taught with conventional instruction methods when the game was supplemented with other instruction methods, when multiple training sessions were involved and when players worked in groups.

Research on digital mathematics interventions has shown increased motivation (Rosas et al. 2003), more positive attitudes towards mathematics (Ke 2009), and a better mastery of mathematics (Praet et al 2014; Steenbergen-Hu et al. 2013; Li et al. 2010; Räsänen et al. 2009) for children in Kindergarten and primary education. All of these studies were conducted with European or North American children. Recently, Pitchford (2015) evaluated the effectiveness of a tablet intervention for mathematics in a school in Malawi. She concluded that tablet technology can effectively support early year mathematical skills in developing countries if the software is carefully designed to engage the child in the learning process and the content is grounded in a solid well-constructed curriculum appropriate for the child’s development stage.

Clark et al. (2008) argue that the choice of media does not influence learning or media. Differences in instructional design prevail over the method of delivery. Usually the difference between passive and active learning and the clear and concise instruction determines variation in learning outcomes. This means that in the use of educational games the design of instruction delivered by these games is of crucial importance. This is in line with Wouters (2009) who argues that the alignment of learning outcomes and game type, the alignment of game complexity and human cognitive processes, attention for cognitive and motivational processes, research on specific mitigating effects, like gender, on game effectiveness should be considered in game design.

1.1 Acquisition of mathematical skills

Research shows that children develop mathematical skills at different levels before beginning formal schooling (USAID 2009). Children across cultures seem to bring similar types of skills to school, but do so at different levels (Guberman 1996). In general, children from low-income backgrounds begin school with a more limited skill set than those from middle-income backgrounds. This is related to the environment in which children grow up that enables them to understand the world, master language and get insight in the basic knowledge needed for mathematics (Greenman 2011). Furthermore, the rate of acquisition of mathematical skills can be influenced by the opportunities children have in their communities (Guberman 1996). Household tasks and chores can get in the way of developing these skills, but they can also enhance the acquisition of these skills because they provide meaningful learning opportunities (buying or selling vegetables). Once children begin formal education, they use this informal knowledge when completing new tasks (Baroody in Copely 1999; Ginsberg 1981).
Between the ages of 3 and 9, the construction of number knowledge develops in more or less the same ways (USAID 2009). Becoming efficient at mathematics requires the automatization of the subsequent stage, rather than repeating the earlier stages. Children need to free up cognitive capacity to be able to solve more complex problems (Pellegrino 1987). With continued practice, children become more confident in their computational and problem solving skills. This puts a significant emphasis on good early mathematics experiences for children.

Across countries, curricular and conceptual goals show similar subjects (USAID 2009):

- developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison;
- representing, comparing, and ordering whole numbers, and joining and separating sets;
- developing understandings of addition and subtraction, and strategies for basic addition and subtraction facts, including whole-number relationships (e.g. tens and ones); and
- developing understanding of base-ten numeration system and place-value concepts, including fluency with multi-digit addition and subtraction.

This means that a mathematics game aimed at the first three grades of primary school, should comprise at least these subjects.

1.2 Game design

The design of the game and its requirements are described in more detail in Stubbé et al. (in press), but this paragraph will provide a short summary. The most important constraint for the game design was that children will use the game in their own remote communities. This automatically implies that there will be no school or teachers. Instruction and feedback will therefore have to be incorporated into the game. Because this project focuses on vulnerable children with little learning support from parents or teachers, we assume them to have little informal knowledge. Besides, the opportunities to learn from everyday life situations in the communities are scarce. Because of this the approach for struggling learners is followed. One of the major issues in supporting struggling learners is to ensure that there is a strong basis to build on. This corresponds with the concept of mastery learning (Bloom 1985), where ‘the students are helped to master each learning unit before proceeding to a more advanced learning task’. Furthermore, struggling learners need explicit instruction (Timmermans 2005; Milo 2003). Research (Bodovski 2007) shows that struggling learners show less engagement during instruction. If this engagement is increased, performance increases as well. A focus on ‘time on task’ (Carroll 1963) could help to improve learning results; for all children can learn mathematics, but some need more time than others. This means that the game should provide active learning, motivate children to increase their time on task, and use individual, continuous assessment in order to provide each child with mini-games that match the level of mastery. In addition, special attention will need to be given to the specific context in which the children live, to avoid children using too much of their cognitive capacity for processing (narrative) information that is not directly related to the learning content (Wouters et al. 2013).

Instruction is provided by short videos (1-2 minutes) per mathematical concept (Figure 1). In the videos, slightly older children, aged 14-15, explain the mathematical concept and show how to approach problems relating to this concept. This has a motivating effect, and helps the children to understand what they need to do. The language used is simple Modern Standard Arabic, which makes it possible for children to understand the instruction, and, therefore, understand the mathematical concept. Children must watch the video once, to introduce a new mathematical concept. Then, they can watch it as many times as they like.

![Figure 1: Screenshot of instruction video](image1.png)

![Figure 2: Screenshot of feedback in mini-game](image2.png)
Children receive immediate feedback on the answers they give (Figure 2). This helps them to know if they are on the right track. The testing underlying this feedback is also used as continuous assessment to determine progress in the game and make sure children always learn at their own level. In addition, feedback on progress is given in two different ways: the children receive stars when they have finished mini-games, and proceed to a next level when they have finished the previous one. The curriculum in the game starts with Kindergarten learning goals. In this way, all children are given the opportunity to build a strong basis before continuing to more complex mathematical concepts. Each mathematical concept can be practiced by a number of different mini-games. First of all, this enables active learning: children are actively engaged in solving mathematical problems. In addition, the diversity of games motivates them to spend more time on practicing a mathematical goal. They feel they are doing different games, while they are, in fact, practicing the same mathematical concept. Last but not least, much attention was given to make the game context specific. For this, children in the remote communities in Sudan were asked to draw their own environment: clothes, food, animals, plants, and family. These drawings were used as a basis for the graphic design. The overall narratives (helping other children to become e.g. a goat herder; a shop where product are bought and sold) fit in with their cultural background. Because children recognize the objects and the narrative, their cognitive capacity can be dedicated to learning the mathematical concepts.

2 Method

This study reports two pilots. Both pilots used a pretest-posttest control group quasi-experimental design. Participation.

In the communities, all children in the relevant age group were invited to participate in the experiment. Parents were informed about the goal and the method. The community was involved in setting up the ‘learning centers’ (sheds where the children gathered to learn). Children were assigned to either morning or afternoon learning sessions, according to their parents’ wishes. In this way learning could fit in with their chores and household tasks.

Learning Sessions and Hardware
Because there were two learning sessions a day, the hardware could be shared. Each laptop or tablet was used by two different children. Consequently, hardware stayed in the learning center, locked away until the next session.

Facilitator
Each community had a facilitator. The facilitator encouraged the children to work with the mathematics game and helped with technical problems. The facilitator was not supposed to teach or explain the principles of mathematics. Facilitators were trained to take this role and to solve technical problems. During the week, they lived in the communities, in the weekends they could go home.

Observer
During Pilot I, observers attended the learning sessions twice a week, to observe if the facilitator followed instructions. In both pilots they tested the children with respect to their mathematical knowledge.

Staggered approach
A staggered approach was used to support the start in each community by the observers and supervisors. Moreover, the technical issues that arose in the first community could be solved before the other communities started. The control groups were tested later.

Oral test
Oral mathematics tests were used because all children were assumed to be illiterate (Pilot I: test A; Pilot II: test A & B). These tests were designed on the basis of the Early Grade Mathematics Assessment (EGMA, USAID 2009), and consisted of 30 items each (maximum score was 60 points), covering the very basics of mathematics. Both tests tested oral counting, number identification, one-to-one correspondence, quantity discrimination, word problems, addition and writing down numbers. In test A the numbers ranged from 1 to 10, in test the numbers ranged from 1 to 20. The same tests were used as a pretest and posttest.

Test protocol
As the children live in remote communities, it was assumed they had not been tested before in any formal way. Reports on the testing of children in developing countries mention that children are shy to answer any questions at all (Kanu 2013). A test protocol was designed, including child-friendly approaches. The observers were trained to use this. During testing, a supervisor was present to ensure that the testing was performed according to protocol.
Ethics
The ethics committee of the Ahfad University for Women in Khartoum has approved these pilot studies. In addition, agreements have been signed by White Nile State, North Kordofan State and Gedaref State and the participating communities. All facilitators signed a child safety protocol. Parents have signed consent forms for their children to take part in the experiment and to be photographed. All data are related to a child-specific number. This was done for privacy reasons, as well as for pragmatic reasons (Arabic names can be spelt in different ways in English). The communities in the control group in these pilots, will participate in a later phase of the project.

2.1 Pilot I
Participants were 67 children in three remote communities in Sudan (Mona, OmTifag, and Wad Almoshmer), aged between 7-11. See Figures 3 and 4 for percentages per gender and age. The control group consisted of 19 children in a fourth remote community (OmOkaz). None of the children had been to school before. The experimental group used the laptop game for a period of six weeks, five days a week, 45 minutes a day, while supervised by a facilitator. The control group did not receive any education in the same period. In addition to the test results (test A, pretest and posttest), the following data were collected: attendance, motivation (observed by facilitator) and the logged data in the mathematics game. At the end of the pilot the children were tested by a nearby school, to assess their Grade level.

Three children were excluded from the experimental group; two because they had been to school before, one because he had been brought from another community and became homesick after only three days. Three children did not take the post-test, seven others dropped out during the pilot. The data from the remaining 54 children was used for analysis. In the control group no children were excluded from analyses.

There was one technical problem in the first week in the first community. Because the game depends heavily on audio and video, children needed earphones to be able to hear the instruction from their own laptop. This was arranged within a week. Furthermore, there was a software problem: the first four levels in the game were adequately developed. For the fifth level, the instruction video had not been included, which made it difficult for the children to understand what they needed to do in that level.

Although unique numbers were used to ensure anonymity, some observers only wrote down the names of the children. Because of the many ways in which Arabic names can be written down in English, it was hard to match the collected data for nine children. In collaboration with the observers, the names were matched with the unique numbers.

2.2 Pilot II
Participants were 591 children in 19 remote communities in three states in Sudan (White Nile, North Kordofan and Gedaref), aged 7-9. The control group consisted of 325 children in 10 more remote communities in the three states. The experimental group used the tablet game for a period of approximately six months, for a maximum of five days a week, 45 minutes a day, while supervised by a facilitator. The children in the control
group were enrolled in informal education; they attended two mathematics lessons a day of 45 minutes each, taught by a teacher in out-of-school centers. In addition to the mathematics tests A and B, the internationally validated Early Grade Mathematics Assessment (EGMA) was taken by independent consultants, with a stratified sample of the children (210) in the experimental condition. Finally, logged data were collected from 532 accounts.

Figures 5 and 6, below, show the percentages per gender and age.

Three children were excluded from the experimental group; one because he was too young (6 years old), two because they had been to school before. Facilitators reported that 57 children dropped out during the pilot. Five more children were excluded on the basis of the logged data: their logged data showed they had only played the game for a short period, and not finished it. The data of the remaining 526 children was used in further analyses. There were, however, some issues with the data collection in the control group: the pretest and posttest were not taken at the designated times. In Gedaref, the pretest of test A was taken two months after the children had started their lessons. Because of this, all data from the Gedaref control group (100 children) was excluded from further analysis. In White Nile and North Kordofan, the pretest of test A was taken at the right time; the posttests, however, were taken later than planned. Instead of an interval of 6-8 weeks, the posttest was taken after three months in North Kordofan (45 children) and after six months in White Nile (180 children). Consequently, the results from these two states were analyzed as two different sets. There were no posttest data for 14 children in North Kordofan and for 34 children in White Nile. The data of the remaining 177 children was included in further analyses. Because of logistic issues, logged data were not collected for two communities (57 children). Also, the matching of logged data to the test data proved difficult, because the facilitators had not used the unique child numbers for this, but had instead used the child’s name. Because names in Arabic can be spelled in different ways, it was impossible to match 23 files of logged data. For 449 of the children in the experimental condition logged data were available and included in further analyses.

Because of the iterative development process used, two updates of the game had to be installed during the pilot period. The progress in the communities in North Kordofan, who started first, was faster than anticipated: they had to wait two weeks before the first update could be installed. Furthermore, two mini-games did not function properly which made it impossible to give the right answers. These bugs were fixed within two weeks.

In general, communities had two facilitators, taking turns supervising the learning sessions. In White Nile, however, there were four communities in which the only facilitator left in November 2014, and the new facilitator(s) started in January 2015, leaving a one to two-month interval during which learning sessions were not supervised.

3 Results

3.1 Pilot I

Pilot I was conducted in the period of December 2012 to February 2013.

There were more boys than girls, in the experimental condition (56%-44%) as well as in the control group (60%-40%). This reflected the situation in the communities; girls were not excluded from the pilot. There was
no significant difference in participation of girls and boys between the experimental communities and the control group.

The children’s ages varied between 7 and 11, with most children at the age of 8 and 9. There was no significant difference between the average age in the experimental condition and the control group (8.3).

The experimental group had an average of 33% correct answers on the pretest (N=67, M=20.3, SD=11.5). The control group had an average of 28% correct answers on the pretest (N=19, M=16.5, SD=5.6). An independent T-test showed no significant differences on the scores of the pretest between the experimental group and the control group (t=-1.4283, df=79, p=0.16). The average score of the experimental condition on the post-test was 55% correct (N=54, M=33.1, SD=15.5), the control group showed a slight increase to 29% correct answers (N=19, M=17.2, SD=5.3). An independent T-test showed a significant difference between the posttest scores of the experimental condition and the control group (t=-4.5059, df=79, p=0.00). Furthermore, an independent T-test showed significant differences on the delta scores (posttest-score minus pretest-score) between the experimental group and the control group (t=9.1, df=71, p=0.00) (see Figure 7). Hence, the experimental group has learned significantly more than the control group.

![Average results Pretest-Posttest](image)

**Figure 7: Results pretest-posttest**

All the children that used the game improved significantly, but children with a lower score on the pre-test, increased their scores more than children with a higher score on the pre-test. The increase varied between 9 and 42 points. There were no significant differences between boys and girls or between age groups.

3.1.1 **Logged data**

The logged data show that with a few exceptions all the children used the game five days a week during the pilot period. Approximately 30% of the children completed all the materials in the game. The other 70% of the children finished between 50-70% of the materials. The children that had finished before the pilot ended were told to start again from the beginning.

3.1.2 **Observations**

Observation forms were filled out daily by the facilitators. They show most children were present during sessions and were motivated to learn most of the time (see figure 8). There were differences in motivation between communities at the start of the experiment, but average motivation increased over the six weeks (from 2.7 to 3.2 on a 4-point scale). In Mona motivation decreased during the first week. This could be explained by the fact that the children did not have headphones, and could not hear the instruction. After this was solved, motivation increased again. In Wad Almoshmer, motivation in the first week was at a maximum. Later, motivation decreased towards a more average level.
The children said they loved the instruction videos very much, and some watched them twenty times. When asked about this, they would say that the older children in the videos were their big brother or sisters (role model); ‘If she can do it, I can do it as well!’ They also loved the many games and the colors in the game.

One of the participating children was a physically handicapped boy. Because of his slurred speech, people thought he was retarded as well. He performed very well with an average improvement of 15 points. He is now more accepted by the other children, and even his speech has improved.

After the six-week experiment the children were taught by teachers in their own community for the rest of the school year. At the end of this period they were tested by a nearby school. Ten children were admitted to Grade 4, five children were admitted to Grade 2 (which would be normal progression) and the rest was admitted to Grade 3. The progress of the ten children admitted to Grade 4 was followed carefully. At the end of Grade 4 they were the top 10 of their year. This shows that the children not only learned their mathematics, but also formed a strong basis for further development.

## 3.2 Pilot II

Pilot II was conducted in the period of October 2014 to March 2015. Participation of boys and girls was almost equal (49% vs. 51%). The average age of the participating children was 7.8 years. Children in North Kordofan were slightly younger (average is 7.4 years), compared to the children in Gedaref (8.0 years) and White Nile (7.9 years). Analysis of the demographic information of the children who dropped out showed no significant effect for gender or age.

### 3.2.1 Test results

To assess if children have increased their scores on test A an Anova repeated measures (SPSS GLM) test within subjects factor: Math-A-PRE en Math-A-POST was used. On average children in White Nile, North Kordofan and Gedaref had 33% correct on the pre-test of test A (20 of a max. of 60 points). The average on the post-test of test A was 68% correct (41 points). This increase is significant (F(1,499)=1170.929; p< .001; r=.85). There were significant differences between the states (F(2,99)=21.710; p < .001; r=.29); White Nile has a higher score than North Kordofan and Gedaref on the pre-test (24 points resp. 16 resp. 19) as well as on the post-test (47 points resp. 40, resp 37) of test A. Posthoc tests (Bonferroni) show that White Nile differs significant (p < .001) from the other two states. There is also a significant interaction between Math and State F(2,499)=9.055; p < .001; r=.21). All three states perform better on the Post-test than on the Pre-test, but North Kordofan has a relative greater increase of scores from pre-test to post-test. This can be explained by the significant differences between age groups, with older children having higher scores than younger children (F(2,499)=14.758; p < .001; r=.25) (see Figure 9). The average age in North Kordofan was lowest, in White Nile children are older.
Figure 9: Average score test A pre-post per age.

Also, children with a lower score on the pre-test showed a larger increase in scores than children with a higher score on the pre-test ($F=29.17$, hypdf=2 erodf=488, $p<.00$, eta=.11). This can partly be explained by a ceiling effect: if children have a higher score on the pre-test, there is less room for improvement. In addition, the first levels of the game addressed more basic mathematical concepts. If children already mastered these, they could not learn much in these levels. There were no significant differences for gender: scores as well as increase of scores were similar for boys and girls.

Because of the data collection issues with the control group regarding the timing of testing, differences between the experimental group and the control groups must be interpreted with caution. Comparisons are made per state, not with the total average scores. A comparison of the North Kordofan (NK) experimental group with the NK control group shows no significant differences, in pre-test, post-test or increase of scores between pre- and posttest (see Figure 10). This is a positive finding, as the NK control group received twice as much instruction per day, compared to the experimental group (2 times 45 minutes, vs. 45 minutes a day). Moreover, the NK control group had a three month interval between pre- and posttest, whereas the experimental group had a 6-8 week interval between tests. Roughly, the NK control group has had three times as much opportunity to learn as the NK experimental group. The NK control group is very small (N=31), which makes it less suitable to compare to the NK experimental group (N=182).

A comparison of the White Nile (WN) experimental group (N= 148) to the WN control group (N=146) shows that there is a significant difference in increase (31 vs 36 points) between the two groups ($F(1,288)=17.034; p < .001; r=.24$). The WN control group on average significantly increased its score more than the experimental group (see Figure 11).
Figure 11: Average results test A, pretest-Posttest, White Nile

It is important to note that the WN control group had (much) more opportunity to learn: they had two mathematics lessons of 45 minutes per day versus 45 minutes in the WN experimental group, and a much longer interval between pretest and posttest (6 months vs. 6-8 weeks). This means the WN control group had roughly six times more learning time than the children in the WN experimental group. The WN control group had 75% correct on the posttest, which means that there was more room for improvement. From this perspective, the difference in increase of scores is rather small. Children in the WN experimental condition have relatively learned more.

To assess if children have increased their scores on mathematics test B an Anova repeated measures (SPSS GLM) test within subjects factor: Math-B-PRE en Math-B-POST was used. The average score of children in White Nile, North Kordofan and Gedaref on the pre-test of test B was 32 (max. 60). The average score on the post-test of test B was 41. This average increase of 9 points is significant (F(1,456)=160.067; p < .001; r=.51). There were no significant differences for gender (see Figure 12) and age groups.

Figure 12: Average results test B, Pretest-Posttest for gender

The pre-test score is remarkably high. This can only partly be explained by the overlap between test A and test B. In the research plan, the pre-test of test B should have been taken at the same time as the post-test of test A. In reality it was taken later. In the meantime children played on, and thus increased their knowledge. This may explain the high average on the pre-test of test B.

Because the order of the curriculum in the game was different from the Sudanese curriculum used in the out-of-school learning centers, the control groups did not take test B: they had been taught the mathematical concepts tested in test B.
3.2.2 Results EGMA

The results of EGMA, taken by 210 of the children in the experimental condition, can be compared to earlier studies with Arabic speaking children in Khartoum and Jordan, because it is an internationally validated test. Figure 13, below, shows that the children in the experimental condition (ELS) had the highest percentage correct in three sub-tests of EGMA (Shapes I, Shapes II and Word problems) after only six months of learning, compared to children who had attended school for 2.5 years in Khartoum and Jordan. In a fourth sub-test (Missing number) the children in the experimental condition had a higher score than the children from Khartoum. The children in the experimental condition only had a slightly lower score on: Number discrimination, Addition level 1, and subtraction level 1.

![Scores EGMA](https://example.com/scores_egma.png)

**Figure 13:** Scores EGMA compared; E-Learning children (ELS), Khartoum and Jordan

There are significant positive correlations between the scores on the mathematics tests A and B (pre and post) and the measurements of EGMA. These correlations are not always strong. The strongest correlations are for Addition level 1, Subtraction level 1 and Problem solving, all correlating more than .50. Although all tests show significant positive correlations with EGMA, the B-Posttest has the strongest correlations. This can be explained by the fact that test B measures more difficult mathematical concepts than test A, and is, therefore, more similar to EGMA than test A. These correlations show that test A and B measure similar concepts of mathematics as EGMA.

3.2.3 Logged data

Most of the children played the game for a period of 5 to 7 months (average 135 days). Girls were found to participate for a longer period than boys (average of 141 versus 129 days; F(1,378) = 7,726; p < 0.05). No differences were found for age. Children from North Kordofan played a significantly shorter period (122 days), compared to White Nile (138 days) and Gedaref (145 days; F(2,377) = 11,114; p < .001). Correcting for both gender and age, children were found to only differ in the number of days between first and last play based on state (F(2,363) = 6.123; p < .05).

On average, most children were found to participate two to three times a week. Figure 14 represents the frequency of playing (average plays per week), in categories. No differences were found for gender. Age was found to be significantly related to frequency of playing: 7-year olds played more often (2.7 days a week) than children 8-year olds (2.3 days a week), who in turn played more often than 9-year olds (2.0 days a week; F(2,377) = 17,909; p < .001). There was also a difference between states: children from North Kordofan played more often (3.2 days a week) than children from White Nile (2.2 days a week), who in turn played more often than children from Gedaref (1.7 days a week; F(2,377) = 143,954; p < .001). Correcting for both gender and age, children were found to only differ in the frequency of playing based on state (F(2,363) = 80.093; p < .001). Frequency of playing is an average that can be the result of playing five times a week for a number of weeks and then skipping one or more weeks, or playing a limited number of days per week.
Although there is a correlation between the number of times played and percentage of the game completed, test results are better for children who participated for a longer period, even if their frequency of playing was lower.

4 Discussion and conclusion

In this study we aimed to test if children in rural areas in Sudan could learn mathematics autonomously, by playing a mathematics game on a computer or tablet, only supervised by a facilitator. To assess the effectiveness of the game two pilot studies were conducted. Pilot I tested a small part of the curriculum (6 weeks) with 67 children playing the game five times a week, 45 minutes a day, supervised by a facilitator. Learning sessions took place in the remote communities. Pilot II tested a larger, and more diverse, part of the curriculum (6 months) with 591 children playing the game 45 minutes a day for a maximum of five days a week. In a baseline study the mathematical abilities of children were assessed. After approximately 6-8 weeks children were reassessed so that learning gains could be determined. In pilot II two tests were used, both with a 6-8 week interval.

Educational research in remote areas in Sudan proved to be a challenge. Although facilitators and observers had been trained to use the test protocol, tests were not taken at the designated times. As a result the pre-test of test B was taken too late, leading to rather high scores on the pre-test. This makes it harder to show significant improvement. Using control groups in developing countries is also an issue: there is an ethical element in asking communities to participate in a pilot as a control group without allowing them to benefit from it. In addition, agreements have to be signed at various levels before communities can participate. As a result the control groups were smaller than the experimental group. Again, in the control group tests were not taken at the designated times, leading to an exclusion of the Gedaref control group, and modified analyses for the NK and WN control groups in Pilot II.

Nevertheless, this study showed that using the mathematics game was more effective than no education, informal education and formal education (for the sub-tests taught in the game) for primary school children in Sudan. In both pilots, all children in the experimental condition have improved their scores on mathematics tests significantly. In pilot I, the control group who received no education did not improve their scores during the same period. This proves that the increase in mathematics scores in the experimental was not caused by maturation or a test effect - as a result of taking the same test within six weeks - but by playing the game. In Pilot II the control groups showed the same or slightly more improvement, despite the fact that they had received three to six times as much opportunity to learn than the children in the experimental condition. To ensure external credibility, independent, trained consultants took the standard Sudanese version of EGMA with a stratified sample of the experimental group in Pilot II. The results show that the children in the experimental condition, who had used the game for approximately six months, had higher scores on three sub-test of EGMA than children in Khartoum and Jordan who had been to school for 2.5 years. On a fourth sub-test the children in the experimental condition had a higher score than the children in Khartoum. This shows that
children can learn from the mathematics game, with only a facilitator to supervise them. There was no significant difference between boys and girls; the game is as effective for girls as it is for boys.

It is important to realize that the children involved in these pilots had never been to school before. In addition, 80% of their parents have never finished primary school and are functionally illiterate. Although mathematics games have been tested in developed countries (Praet et al. 2013; Räsänen et al. 2009), and even in schools in developing countries (Pitchford 2015), this is the first time a mathematics game was tested with this specific target population: out-of-school children in remote areas without any access to school, teachers or learning materials. Representatives of the Ministry of Education in Sudan who have visited the communities during the pilots, and the consultants taking the EGMA test with the children expressed their surprise at how much the children were learning and how confident they were about their knowledge.

In general, children with a lower score on the pre-test of test A improved more than children with a higher score on the pre-test. This is probably due to a ceiling effect: the game and the test focused on the very beginning of mathematics. Children that already had some knowledge of mathematics, achieved a higher score on the pretest and thus had less room for improvement. In addition, the game taught the basics of numeracy and addition. Children who knew how to do this could not learn very much from the game. They were the ones that went through the initial mini-games quickly. Others took longer to understand the basics of numeracy. Since the game offers children the possibility to learn at their own pace, they would always be playing mini-games that suited their level of mathematical skills.

During Pilot I children played the game for six weeks, five times a week. Pilot II was organized similarly: facilitators provided learning sessions for six months, five times a week. However, the logged data showed that the majority of the children only played an average of two to three times a week, thus decreasing allowed learning time by almost half. Although the learning results would probably have been better if children had participated five times a week, progress was still good. This shows that the use of the mathematics game allows children to learn at their own pace: if they skip learning sessions for a day or a week at the time, they can always come back and continue where they left off. In a more formal classroom environment this would be very difficult; children would have missed instruction.

When children learn autonomously, without a teacher to give instruction and feedback, and motivate them, there is always the issue of motivation. Will they stay motivated to keep on learning for a longer period of time? During Pilot I average motivation stayed high, and increased slightly. During Pilot II, focus group meetings were organized with children and parents. In discussions, both groups indicated that they liked learning and playing the game very much.

The most important goal of this study was to prove that children can learn from playing the mathematics game. As this method of learning is completely different from what is generally used in Sudan, a ‘proof of concept’ was needed before the rest of the game was developed. Both pilot studies have shown that children can learn, autonomously, using the mathematics game. Tablet technology, including well-designed, curriculum-based, engaging software, could help reach the 2.3 million out-of-school children in Sudan and teach them the basics of mathematics. Although teachers play a very important role in children’s learning and children should attend school, this game can provide learning for those who have no access to school (yet).

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