Learning also needs to be a little fun: what academic learning goals can students achieve by developing games?

Apprendere dovrebbe essere anche un po' divertente: quali obiettivi scolastici possono essere raggiunti sviluppando giochi?

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ABSTRACT This study presents an exploratory investigation of how learning through game development can contribute to students' academic learning and how applying game making for learning as a teaching method can be linked to subject-specific learning goals. The paper describes a project where twenty-two second grade Danish students worked with problem-based assignments that supported them in developing digital games for learning with the Scratch tool. The students succeeded in creating digital games for learning and in embedding learning situations, learning activities and evaluation opportunities into their games. Analysis of the learning dynamics suggests that the students were involved in interactive communication and production processes and used the Danish language as a tool inside their small digital games when engaging in this problem-based and constructionist learning approach. According to the analysis, the students managed to work with specific academic learning goals and enjoyed learning through the development of games for learning.

KEYWORDS Game Making; Game-Based Learning (GBL); Students as Game Developers; Problem-Based Learning (PBL); Constructionism.

SOMMARIO Questo articolo presenta uno studio esplorativo sul contributo che l'approccio didattico basato sullo sviluppo di giochi può fornire al raggiungimento degli obiettivi scolastici. L'articolo descrive un progetto in cui ventidue studenti danesi del secondo anno di scuola primaria sono stati guidati con un approccio basato sulla soluzione di problemi nello sviluppo di giochi digitali per l'apprendimento con lo strumento Scratch. Gli studenti sono riusciti a realizzare giochi digitali educativi per i loro compagni incorporando nei loro giochi situazioni e attività di apprendimento oltre che opportunità di valutazione. L'analisi delle dinamiche di apprendimento ha rivelato che il processo di apprendimento costruzionista e basato su problemi ha coinvolto gli studenti in processi comunicativi e di produzione linguistica nella loro madrelingua e li ha portati a usare il danese anche all'interno dei loro piccoli giochi. L'analisi ha inoltre rivelato che gli studenti hanno conseguito specifici obiettivi di apprendimento curricolari e hanno apprezzato l'approccio adottato.

KEYWORDS Sviluppo di Giochi; Apprendimento Basato sui Giochi; Studenti che Producono Giochi; Apprendimento Basato su Problemi; Costruzionismo.

1. INTRODUCTION

Teachers and researchers active in the area of learning and technology have long argued that games can be used as an active and motivating way to learn through experience. In carefully designed educational games, students can, for example, have the opportunity to engage in learning situations that could not take place in a traditional classroom (Barab & Dede, 2007; Squire, 2011; Gee, 2003). Similarly, commercial games can be used with educational purposes (Amory, Naicker, Vincent, & Adams, 1999). However, in response to the debate on whether learning potential can be best realised through the use of commercial games or educational games, some researchers maintain that there is an alternative to these two routes (Kafai & Burke, 2015). Perhaps we should instead consider whether we can learn best by playing games or by developing games. A growing number of researchers are investigating whether it might be advantageous to expand game-based learning strategies – for example, the use of virtual worlds, simulations or games developed with the specific purpose of learning – to include the *design of games* as a means of learning (Earp, 2015; Kafai & Burke 2015). That is, instead of giving the student the less active role as a player, we could choose a learning approach where the student learns by designing games (Oygardslia, 2015; 2018) (Weitze, 2016a; 2016b, 2017a). The more active role as game developer demands that the student must be innovative, make complex choices and apply creativity in a problem-based learning approach, offering many new possibilities to learn about relevant academic subject matter in this process. But how should a teacher design a teaching situation if she or he wants to let students create and learn through the design of technological artefacts and, at the same time, achieve curricular objectives? To create a learning design where students can reach formal learning goals by developing digital games, teachers, who are often novices, need support in relation to the creative and productive use of technology.

This study experimented with creating an overall learning design with the purpose that students from second grade (8–9 years old) could work towards achieving academic goals, specifically Simplified Common Goals[1] (SCGs), in Danish as a subject matter by developing digital educational games for their classmates using tools and methods from constructionism in a formal learning environment. The idea behind this approach is that students should become designers of their own learning process and in this way reach their learning goals through collaboration, game making and peer discussion of ideas and possible solutions.

1.1. *Background for game development as a learning approach*

Seymour Papert founded the constructionist pedagogical approach, that is, the theoretical argumentation suggesting that students can learn through designing and creating (Harel & Papert, 1991; Kafai & Resnick, 1996). In the process of exploring how to learn by creating, Papert, starting in the 1960s, developed and studied digital tools such as Logo and later Lego Mindstorms at the Massachusetts Institute of Technology (MIT) Media Lab (Papert, 1980). These tools have since been further developed by the Lifelong Kindergarten research group at the MIT Media Lab, resulting in the programming environment Scratch[2], which was launched in 2007 (Brennan, 2014).

[1] SCGs are national goals that describe what the students should learn at each grade level and in the individual subject matters (Universal Verification Methodology, 2018). In Danish for second grade, students work with language and texts in context as well as the following areas of competence: reading, production, interpretation and communication. The focus is on communication as interaction and language as a tool.

[2] Scratch [Computer software]. (2018). Scratch 2.0. Developed by the Lifelong Kindergarten Group by the MIT Media Lab. Retrieved from http://scratch.mit.edu

Programming technology offers new opportunities for creative and innovative expression, and this gives students the opportunity to develop their own ideas and worlds through the use of technological tools. This potential has led to a large number of initiatives aiming at teaching students to code and create with technology. For example, Code Club[3] has established 10,000 clubs in 100 countries where children can learn to code, and in Great Britain *programming* has become part of the learning goals in primary education. In the United States President Obama led a campaign that acted on *Computer Science for All*. This movement invested in and worked on developing possibilities for schoolchildren to learn computer science and develop computational thinking skills – students 'need to be creators in the digital economy, not just consumers, and to be active citizens in our technology-driven world' (Smith, 2016). Similar initiatives are being considered and effectuated in many other countries. The ability to code and obtain an understanding of the logic of the technology behind the interface can be described as *computational thinking* (Brennan & Resnick, 2012; Freixo Nunes & Loureiro Cardoso, 2017; Wing, 2006, 2017). The argument is that as students learn to design with these technological tools, they are also able to move from the role of technological consumers to the role of producers of digital content (Koh, Chai, Wong, & Hong, 2015).

The constructionist pedagogical approach is at the heart of the maker culture[4], which emphasises learning-by-doing individually and in collaboration with peers (Ratto & Boler, 2014; Resnick, 2017). The maker movement is a participatory movement with an artisan spirit that uses technology as «*an emancipatory tool that puts the most powerful construction materials in the hands of children […] engendering a convivial environment in which students can concretize their ideas and projects with intense personal engagement*» (Blikstein, 2013). This self-expressive view of the makers' possibilities can be interpreted as a student-maker-directed learning environment. The maker culture can be said to be located in the gap between formal and informal education. This creates an opportunity, both in research and in practice, to understand learning and education as related but independent concepts that can enrich each other (Halverson & Sheridan, 2014). Some researchers believe that the maker culture has the potential to transform what is understood and counts as learning, learners and learning environments (Halverson & Sheridan, 2014), and can help to support the development of future innovative technological entrepreneurs. Other researchers regard it as conducive to avoiding the potential risk that makers 'stay in the sandbox' and never get beyond the hobby stage (Jenkins & Bogost, 2015). Investigating how game development can help students achieve formal learning goals in traditional subject matters could help to enhance strategies regarding how to apply learning-by-creating and the play-like exploration it invites, thereby making the development of digital games for learning a relevant area of formal learning.

2. RESEARCH AIMS

This paper presents an exploratory study intended to improve understanding of how game making can be used to support the attainment of Danish language learning goals in a second grade primary school in Denmark. To this end, the study field tests a learning design (Weitze, 2017a, 2017b) for improving academic competence by involving the students in developing educational games to be used by their peers.

According to this learning design, the students develop their educational games with the support of their teachers, and the academic learning goals are addressed and examined in their individual and collaborative learning processes (Sfard, 1998). The learning design is based on a problem-based learning approach and is

[3] https://codeclub.org/en/about

[4] The "maker culture" has been defined as the activities and ideas of people who create or invent things, either using traditional crafts or technology" (Cambridge University Press, 2019).

inspired by a constructionist educational paradigm. The learning design is grounded on the hipothesys that there is a strong correlation between game making and learning and that the activity of creating, building or programming provides a rich situation for learning (Harel & Papert, 1991; Kafai & Resnick, 1996). To this end, students' self-regulated learning competences are developed by enabling them to make important decisions about their learning process and engage in metacognitive discussions.

3. RESEARCH METHOD

3.1. *Participants and learning environment*

The participants in this study were 22 eight and nine-year-old children in the second grade of a Danish Primary school. The students participated in two five-hour workshops on two consecutive days. One researcher (the author of this paper) with expertise in learning design and Scratch programming planned the basic part of the educational experience, including the game design activity. The teacher of Danish had participated in two preliminary one-hour meetings with the researcher concerning the teaching method in early summer 2016. The aim of these meetings was to discuss the design of the workshops as well as the academic learning goals for this learning design. The Danish teacher suggested the learning goals for the students, co-created the learning design and also participated in both student workshops. The maths teacher took the role of assistant teacher and attended the first day as a support for the class.

The students, with their teachers, had previously worked with Scratch as six and seven year olds in two full-day workshops, one held in K0-reception year and the other in first grade. Although previous research (Kafai & Burke, 2015) suggests that children need to be around 10 years old before they are able to engage in game design, in this case younger children were involved in the belief that positive results could be obtained at this age as well, considering their previous experience with Scratch. The educational experience carried out in this study is described in more detail in section 4.3.

3.2. *Research approach, data collection and analysis*

The study used a design-based research (DBR) approach (Amiel & Reeves, 2008), where the researcher and the teachers participated as co-designers. Open and semi-structured interviews were conducted with the Danish teacher in preliminary meetings as well as after each workshop. The maths teacher was also interviewed twice during the workshops. The interviews and workshops were recorded on audio and video. Interview data were analysed after each preliminary interview and thus informed the development of the general learning design through an iterative process between each interview. The researcher observed and participated in both workshops. Other sources of data include field notes and videos of students discussing and play testing the games, as well as the actual digital games the students developed using Scratch. The analysis was conducted by coding the transcribed data with a qualitative research approach based on informed grounded theory (Thornberg, 2012). The analysis was both performed as concept-driven coding (using concepts from theory and previous empirical data to find themes in the data) and data-driven coding (reading data to search for new phenomena about the topic).

4. CREATING A LEARNING DESIGN FOR LEARNING THROUGH GAME DEVELOPMENT

The following firstly explains the theoretical model for designing games for learning that was used as the framework for the students' game development process (4.1). Following this is a description of how we

explored which learning goals were relevant for this learning approach – 'learning through making games' (4.2), and finally the process of creating the learning design for the experiment is explained in more detail (4.3).

4.1. *The Smiley Model – A theoretical model for designing games for learning*

The educational experience was designed according to the Smiley Model (Figure 1), a design model for creating engaging games for learning that can be used for combining learning design and game design (Weitze, 2016b). The concept of *learning design* can be defined as 1) how a teacher shapes social processes and creates conditions for learning and 2) the phenomenon whereby each student constantly recreates or "redesigns" knowledge in his or her own meaning-creating processes (Selander & Kress, 2012, p. 2).

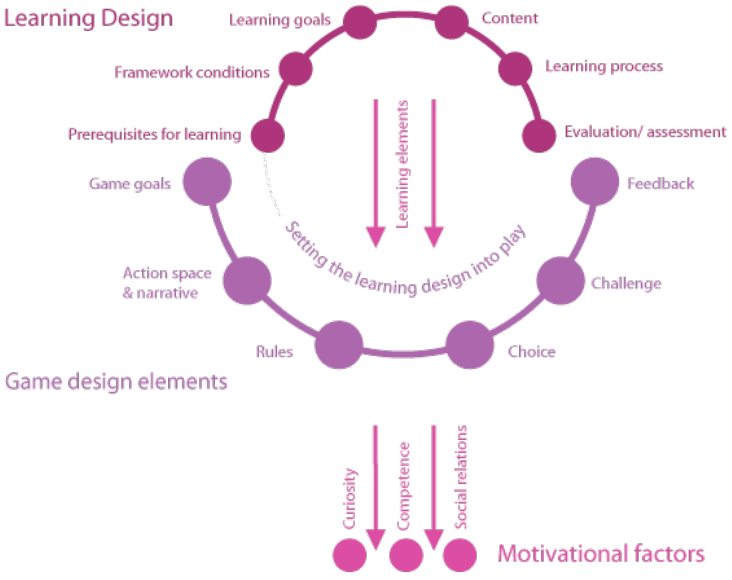

Figure 1. The Smiley Model (Weitze, 2016b).

The Smiley Model combines three essential areas for creating a motivating game for learning. It addresses the need to design the learning process and focuses on setting the learning elements into play through traditional game elements as well as the need to design in a way that awakens the student's/player's intrinsic motivation (Weitze, 2016b). In this study the Smiley Model formed the theoretical framework for shaping students' game-development assignments, guiding them as they created games for learning with specific learning goals, learning situations and evaluation possibilities with the intention that fellow students could learn by playing these games.

4.2. *Preparation phase – Which learning goals are relevant when learning through the development of learning games?*

Traditionally a teacher uses Simplified Common Goals (SCGs) 'top-down' when planning teaching. For example, the teacher may decide that she would like the students to improve their production abilities. In SCGs this is then broken down into specific knowledge, skills and competence sub-goals that the students

should then achieve in order to reach the overall learning goal. In this project, this process was reversed, as the educational aims were defined 'bottom-up'. We investigated which sub-learning goals from the SCGs would be relevant and possible to reach through students' development of learning games. At the start of the project, the Danish teacher and the researcher thus discussed which sub-learning goals from Danish SCGs we could imagine would be appropriate to work with in this game-based learning design. Before the workshops were designed and implemented the learning goals proposed by the teachers were compared and adjusted according to previous research findings concerning what the same cohort as well as other students had previously learned through the development of games for learning (Weitze, 2016b, 2017a, 2017b).

4.2.1. *Learning goals guiding the overall learning design*

We identified many potential SCGs as relevant to this learning approach (see Table 3). For example, learning goals from SCGs such as 'The student can follow the course of a narrative' and 'The student has knowledge about the beginning, middle and end of a narrative' were incorporated into assignments in which the student game developer was to create a game with the following structure:

- Design a game for learning so the player/learner of your game will experience the following:
- At the beginning: the player/learner is invited into a learning situation in the game.
- In the middle: the player/learner experiences successive learning situations and learning activities – or learning opportunities – in the game.
- At the end: the player/learner is evaluated in relation to the content that you, the game developers, wanted the player to learn.

The knowledge, skills and competencies that the students must acquire in a subject matter is of importance to the specific design of the learning process and content in the game – it is not only important *how to learn* when learning through game development but also *what should be learned*. In Danish, for the second grade, the focus was on reading, production, interpretation and communication. These were therefore the areas that the teacher supported her students in working with when learning through educational game development. The chosen learning goals (SCGs) in the current learning design also involved the following: 'The student must deal with communication as interaction [in a learning game] and be able to use language as a tool [to teach with inside the game]'. To work with and achieve learning goals regarding reading, production, interpretation and communication the students had to choose suitable, relevant content that their games could 'teach'. The teacher decided that the students' games should teach about various characteristics of specific animals. Students therefore used a relevant website with small academic e-books about animals. The teams studied the books, selected a book on a specific animal and read the book thoroughly. All teams came up with three specific learning goals that their small digital games for learning would address – for example: after playing this game, the player must know that…/be able to…. The purpose of these learning activities was thus that students worked with reading, production, interpretation and communication, learned to deal with communication as interaction, and became able to use language as a tool.

4.3. *The learning design for the workshops*

The goal of the learning design was that pupils in second grade in the subject of Danish would achieve specific learning goals through developing digital games for learning. The overall learning design for the class included problem-based assignments aimed at supporting students in constructing digital games for learning. As both the students and teachers were novices in game development, written assignments helped to structure and scaffold the learning process.

The learning design entailed that teams of students would achieve specific learning goals while building and implementing self-chosen content into small learning situations in their digital games. In other words,

the student game developers learned while creating small learning designs to be incorporated into small games. In addition, they also learned by discussing and playing each other's games through peer learning, thereby gaining knowledge, skills and competencies within the relevant academic subjects. Table 1 shows a schema of the activities carried out in workshop days one and two.

Workshop day one	Workshop day two
Learning activities in Scratch Introduction to simple example of a digital game for learning Each team searching for three academic facts to teach about from academic e-books Planning the narrative, learning and evaluation situations in the game Starting to code the game incorporating learning situations Common discussion of how far each team has come regarding implementing learning situations as well as digital construction	Continuing creating and coding the game Discussion of and implementation of evaluation possibilities in the games Game test and peer review – presentation of each of the 11 games to the entire class and feedback from class Evaluation conducted by the Danish teacher: 'what have we learned?' regarding academic subjects and computational thinking

Table 1. Schema explaining what was done in workshops 1 and 2.

4.3.1. *Preliminary learning activities in Scratch*

At the beginning of the first workshop, after a short introduction to the project, students had to complete small assignments in the game development tool Scratch for about one to two hours. By completing these assignments, the students learned, for example, to orchestrate turn taking in a dialogue by displaying messages inside the game, change backgrounds by displaying messages and handle events so that certain characters would appear and/or disappear from a scene when changing the background. Students also viewed video demonstrations of three varieties of feedback mechanics in Scratch for answering questions. The students were introduced to each assignment on paper and through short videos. By imitating the principles of what happened in the videos, the students effectively provided personalised individual responses to the assignment task. These basic assignments provided the students with the computational skills needed to create their own small learning games. Reciprocal teaching techniques where often used in order to reward student achievements and reduce the teachers' workload.

4.3.2. Example of a simple digital game for learning

A good learning game not only facilitates learning but also foresees an evaluation process inside or around the game. Therefore, if one is to learn by playing and/or developing a learning game, the game must incor-

porate learning situations that present learning content/knowledge, and also include an evaluation process that tests the player's grasp of that knowledge (Weitze, 2017b). This resembles the recommendations from the Smiley Model (Weitze, 2016a).

However, previous research has shown that it can be difficult for students to form a mental model of the various educational game design elements (Weitze, 2016a), and for a novice game developer it can be difficult to come up with an idea about how to implement a learning process in a game. Often students end up creating quiz games, providing a question with a number of possible answers. The problem with quiz games is that they only allow for a summative evaluation of existing knowledge; they do not teach new content – except for what is learned through trial and error.

Therefore, the students in the project were presented with a simple example of a digital game for learning in Scratch in which the game character considers how to implement learning goals/new knowledge into a learning game (Weitze, 2017a). The students were thus introduced to the learning elements through a game example that walked them through a learning game development process at a combined practical and conceptual level. In the game example, the character first reflected on what learning goals he should choose for the game and then selected relevant knowledge, skills and competencies (content). Next he considered which learning activities would be relevant to teach and learn about the content, presented the content through activities in the game, and finally selected and conducted an evaluation process in the game. This simple game example served as an inspiration for the students, showing the principles for how a learning game could be constructed.

4.3.3. *Pedagogical approach when learning through the design of learning games*

Students in this second-grade class were asked to participate in solving the complex problem of designing a digital game for learning where their audience, the player/learner of the game, could both learn and be evaluated in the game. Since the design of a digital game for learning can be regarded as a complex problem, we used a problem-based learning approach for the learning design (Savery, 2015). The students participating in this explorative study did not have previous knowledge about how to create digital games for learning and implement specific learning goals into a game. They therefore gained new knowledge as they developed their games.

After the initial assignments using the Scratch game tool, students were guided through the complex learning game development process. The students formed 11 teams of two and were set new paper-based assignments that asked them to outline what they would teach inside their learning games – the learning goals of the games. They had to choose three academic facts from an academic e-book, consider how they would teach about the three facts inside their games and how they would evaluate whether the players had learned what the game taught. Then they had to describe how they imagined the beginning, the middle and the end of their learning game. The teachers supported the students in the development of their games if they had difficulties in imagining and conceptualising how they could create their game for learning and ensure it included the teaching and evaluation of their learning goals. Using this problem-based approach, the students managed to create very individual games as they themselves came up with relevant stories, instruction and evaluation processes for their games.

4.3.4. *Game test - peer review*

After finishing the games, each team in turn presented their learning game to the class on the whiteboard. The students read aloud their own game characters' dialogues from the various learning game scenes. When the teams came to the evaluation part of their learning games, they challenged their classmates to answer

based on what they had learned from the game by asking them to choose from the evaluation options that the game offered. This collaborative learning process allowed all the students to learn through each of the presented educational games.

5. RESULTS

The purpose of the research project was to investigate how game development could contribute to students' academic learning processes and be linked to Danish SCGs. This results section therefore begins with a description of how the Danish teacher and the researcher chose to implement the SCGs with a tool that could also be used to detect signs of learning during the workshops. Sections 5.2–5.6 describe examples of how the students worked towards the SCGs by creating game stories, as illustrated in two game examples. This was done by creating fairly complex digital games; by learning 'around the games' as they built learning and evaluation situations involving academic subjects into the games; by engaging in constructionist learning processes whereby learning occurred when the materials 'respond' to them as student game developers; and finally by engaging in collaborative learning processes as they co-constructed and discussed the games. This description is followed by a summarising analysis of how all these learning processes contributed to the students reaching the sub-learning goals from the SCGs.

5.1. *Operationalised learning goals and signs of learning*

To investigate how learning through game design could contribute to students' academic learning as well as how the application of learning game development, as a teaching method, could be linked to subject-specific learning goals, the teacher and the researcher developed a tool that could guide as well as evaluate implementation of the learning design. To target the SCG sub-learning goals for this specific learning design, we operationalised the proposed SCGs (see Table 3) into the teacher's personalised learning goals for the students and also elaborated signs of learning. The following table (Table 2) represents the interpreted and operationalised relevant SCG sub-learning goals in three categories: a) the teacher's learning goals for the class, b) learning goals for the students and c) signs of learning. These goals and points of evaluation were used to guide the following: 1) execution of the specific learning game development assignments in the workshop, and 2) the teacher's instruction and formative evaluation processes during the workshop. Furthermore, these operationalised goals and points of evaluation, together with the formal SCG sub-goals (Table 3) for this learning design, were used by the teacher and researcher after the workshops as analytical tools for discussing and analysing a) the students' individual and collaborative learning processes, b) the students' discussions, and c) the form and content of the digital games for learning. The purpose of this analysis process was to investigate which of the intended SCG sub-learning goals (see Table 3) the students succeeded in reaching.

a) The teacher's learning goals: The student can…	
Find relevant information on a given topic, such as an animal on a particular website. Use the facts they find for their story in Scratch. Create a story/game in Scratch that fosters learning and provides an evaluation process for the receiver. Follow instructions. Write a descriptive academic text about an animal. Talk about and evaluate their own work process from idea to finished product. Provide constructive critique of other students' products. Ask constructive questions about other students' products. Tell what he/she has learned during the process. Work with a partner on a task and talk about possible solutions.	
b) The students' learning goals:	c) Signs of learning: The student has…
Find information at www.fagbog.gyldendal.dk about an animal that I choose myself. Teach three facts about this animal in my learning game in Scratch. Create a story with a beginning, middle and end in Scratch that can teach about the animal and examine whether the player has learned something in my game. Follow instructions on the whiteboard. Listen to the other teams when they present. Present my product to the class. Tell what I have learned while working. Work with any partner when carrying out the assignment.	Used the search function and the menu of an age-suitable website that the teacher has selected, for example, about animals. Used at least three facts in the story/game in Scratch. Created a story/game in Scratch that permits learning as well as evaluation for the receiver (knowledge about how to create a learning design). Followed the instructions that were shown on the whiteboard. Presented his/her product to the class. Explained what he/she has learned during the learning game development process (academic knowledge and computational thinking skills). Listened to other students and explained what he/she has learned from their creations (collaborative learning). Participated actively in the assignment and has been careful to allow room for his/her partner in the team.

Table 2. The teachers' interpretation of SCG sub-learning goals and points of evaluation – signs of learning.

5.2. *Learning through creating a learning situation – or game story*

When creating a learning game in the above-described workshop setting, the young learner/game designer must choose a space for action and a narrative forming a game story (Weitze, 2016a). In addition, the educational game developer must choose how the knowledge, skills or competencies that he or she wants the future player to acquire should be represented inside the game. For example, the game developer must decide how this knowledge may be part of the learning situation in the game in a natural way – in the game's action space and narrative.

In the design of digital games the students often chose to present the new knowledge – what the player should learn – as dialogues between characters in small meaningful game stories or learning situations. Some teams created several consecutive learning situations. Almost all the teams also managed to follow the learning situations with an opportunity for the player to be evaluated on what was learned in the game. The following two learning games are characteristic examples of the 11 learning games created and the elements they contained.

5.2.1. *The wild horses – Learning game example*

In the first example, two students had selected three academic learning goals for their game from an academic e-book about horses. The students had created two dialogical learning situations: one set in a forest and another by a stream. These two scenes formed a beginning and a middle for their game (Figure 2). Subsequently the game challenges players in two consecutive evaluation options/situations – similar to an ending of the game story. The players are provided with feedback on whether they had reached the learning goals of the game.

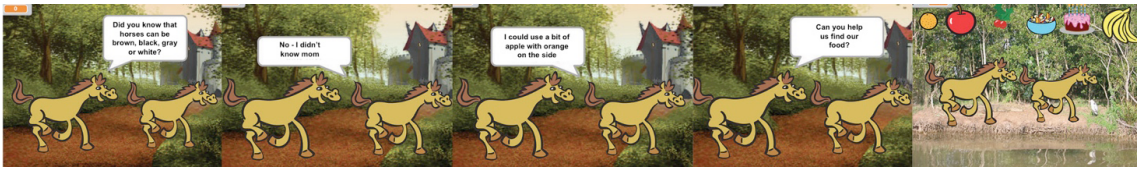

Figure 2. Scenes in the learning game 'The wild horses' (translation by author).

The player/learners smiled and seemed happy when they succeeded in answering the questions in the games appropriately.

5.2.2. *The shark and the man*

In the second learning game example, two students had chosen to teach about characteristics of the shark (Figure 3). Once again, the students presented specific academic *learning goals* through the dialogues in the game story. The game has two stages, one where a diver starts by jumping off a pier into the water, and another at the ocean floor; during the story the diver swims up to his boat and collects fish to feed the shark. These scenes created a beginning and middle in the game story. The ending to the story consists in three consecutive evaluations.

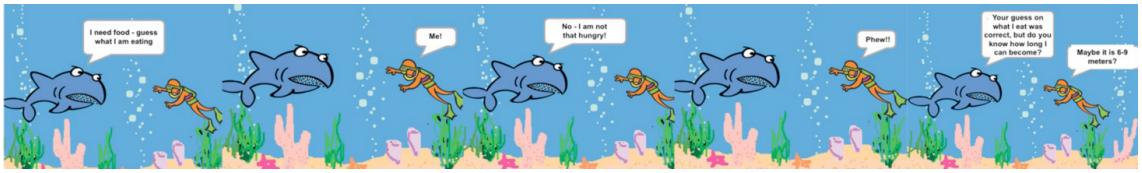

Figure 3. Scenes in the learning game 'The shark and the man' (translation by author).

This game has a long and humorous dialogue between the two game characters, the shark and the diver. The classmates found this dialogue funny and wanted to play the game several times.

5.3. *Higher level of complexity in the games – greater opportunities for learning*

Complex learning games can have long narratives and complex possibilities of learning through activities in the game. The game goals in most of the students' learning games were for players to view/listen to the story to the end and discover whether they could handle the evaluative challenges. The games therefore were relatively simple but still not trivial.

Greater complexity means it is possible to implement multiple learning situations and more content as well as display multiple systemic connections – cause and effect in relation to the knowledge, skills or competencies – the player can learn about by playing the game. The design of more complex learning games can therefore enable a very educational learning process for student game designers, as they need to find content, map connections and create meaningful learning situations for future players (Weitze, 2016b). Though the learning games in the current experiment were simple, the second-grade game developers managed to find content and create learning goals, learning situations, learning activities and evaluation opportunities, as well as implement these into their digital games.

5.4. *The game designers' learning process around the games*

As the students learned through digital educational game development, most of the learning process happened within the design process – as the students co-innovated, designed, critically examined and selected learning goals, academic content, evaluation possibilities and computational strategies. The interviewed teacher, who performed formative evaluations with the students all through the learning game development processes, stated that the students were highly targeted in their production of learning games and focused as they worked. They worked in pairs and also received help from other teams if a function in the digital game was difficult to create. The teacher continuously asked the students to consider how they could design the games for learning so their future player would both learn something inside the game and have the opportunity to be evaluated. To illustrate this, she often referred to the simple learning game examples (section 5.2.1 and 5.2.2). The teacher guided the students by asking for the learning goals of each game. The teacher also sometimes supported the teams by using her content-area knowledge to help them develop ideas on how specific learning goals could be presented in the games. According to the teacher's evaluations, the students reached the intended SCGs (Table 3) while they learned (individually and in teams) through negotiating and selecting academic content, creating small games for learning, and discussing what would be the best ways to present the selected learning goals and knowledge in their games. At the same time, the students also wanted to create entertaining stories in their games that would amuse their fellow students as their played each other's games.

The students took responsibility for their own problem-based learning processes by working hard to solve the problem of developing a digital game. One student in the class experienced his role as an educational game developer like this:

> *«I think it's .... in principle it's fun, but you also have to do something yourself. Instead of the adults making an assignment and giving it to the kids, you have to do most things yourself. For example, when you have to do maths – then you just get an assignment. When you finish that, then you can do another assignment. – Here, you, in a way, have to be the adult yourself and make an assignment that the others must solve. Then it's also fun afterwards when you get to try each other's games, then you also get smarter from*

doing that. And if you want to work with making games when you grow up, then you have already started here. But I think it was fun – learning also needs to be a little fun!»

Consequently, the students learned by being their own learning designers and controlling their own innovative learning processes involving digital technology. They discussed the technical issues, found relevant academic content and examined how they could create learning situations in small digital games. Additionally, the students designed learning options for future players/students who would play their learning games – that is, their classmates.

5.5. *Learning through the use of materials*

Seen from constructionist and problem-based learning approaches, the development of learning games offered many learning opportunities. Learning and creative development can happen when the materials act in unexpected ways during the design process (Schön, 1992). The students needed to develop a meta-level understanding of how to teach and evaluate in a digital game for learning and furthermore to implement and work with this understanding. This brought about many interesting and detailed conversations and discussions between team members as well as between students and teachers, such as discussions on how to teach inside the game and how to choose and develop digital methods of evaluation in the game. Several of the students felt that, for example, their learning game concept in the game development tool Scratch 'teased' them, that they were 'stuck' or that the learning game evolved in directions other than those they had intended in their initial vision. This perceived 'resistance' made the students consider alternatives and create new visions for their games and thereby learn. To deal with the debugging problems, the students used their notations on the whiteboard revealing who had mastered the construction of specific Scratch events in order to know who to ask for help. To make the time-consuming debugging, help-seeking situations work, the rules in the workshops became 'you need to ask two other students for help before asking the teachers'. So the students acted as assistants for each other. Each time they encountered difficulties in the creation of relevant learning dialogues or learning and evaluation situations, in the iterative development work with the game development tool, or in the ongoing discussions the students developed the skills and competencies to create digital games for learning individually and through collaboration. Though the iterative game development processes, with its trial and error, troubleshooting and debugging, could become hectic, this student-assistant approach worked well, and these learning processes contributed to the development of the students' computational thinking skills.

5.6. *Collaborative learning processes*

At the end of the two workshops all 11 teams had created a learning game. Nine games had more than one learning situation/scene, and in 10 games the students succeeded in creating evaluation processes in which the player/learner could either be evaluated by choosing the correct object as a response or by choosing the correct answer out of three or more. Each student team presented their game at the whiteboard, and the whole class acted as the player/learner listening to the game dialogues and answering the questions. At the common play test/peer review of each game, the teacher asked all the students in the class to discuss what they had learned in this specific game. The classmates responded in a lively manner and also made several suggestions about how the game could be expanded or improved (Figure 4).

Figure 4. The students present, play test and discuss the learning games.

The teacher also asked what technical skills each student had acquired in relation to using the game development tool Scratch. The teacher made it clear that these technical skills were now part of the student's expertise and that he or she in the future would be able to help other students within their new skill area.

5.7. *Reaching SCGs in the experiment*

After the workshops, the Danish teacher and the researcher returned to the proposed SCG sub-learning goals for the subject matter of Danish for second grade (Table 3). This list was analysed and compared to the teacher's operationalised learning goals and signs of learning (Table 2). A few of the proposed SCG sub-learning goals were removed, and a few new ones were added. Table 3 shows an excerpt of the final list of relevant SCGs linked to examples of how the students worked with each sub-goal. These results build upon the analysis in sections 5.1–5.6 and were supported by the researcher's observations of signs of the students' learning process during the two workshops. These observations were confirmed by the teachers in the final interview. The analysis indicates that the students were deeply involved in many interactive communication and production processes and that they used language as a tool inside the small digital games as well as in all negotiations and joint decision making in the game development process. This analysis therefore suggests that the students managed to work with the specific academic learning goals from SCG for Danish as a subject matter[5].

Table 3 is an excerpt from the complete table presenting the relevant SCGs the students worked with in this learning game development experiment, connected with empirical examples. This is based on what the analysis in sections 5.1–5.6 indicated and what the researcher and the Danish teacher observed.

[5] IT and media is a cross-disciplinary theme in the Danish subject. Beyond the subject-specific content within each subject matter, the student should also learn about cross-disciplinary themes.

Simplified Common Goal (SCG)			Example from empirical research
Reading:	Text comprehension	Knowledge goals: The student has knowledge about the correlation between the information in the text and the reader's knowledge.	Students understood that they had to choose information from the texts they read, with the purpose to use it for teaching other students/readers about three academic facts. They understood that this would improve their fellow students' knowledge, giving them the opportunity to learn.
Production:	Production	Skill goals: The student can prepare simple texts with title, start, middle and end.	Students created small learning games with text- and graphics-based stories with a start, middle and end and argued for the choices they took in the development of their own games.
	Presentation and evaluation	Knowledge goals: The student has knowledge of simple evaluation criteria.	In the collaborative evaluation process the students demonstrated, that they understood that they and their fellow students had reached the knowledge goals involving the following three parameters: 1) what (academic) knowledge they had achieved, 2) whether the game taught as well as evaluated the learner/player and 3) what programming skills they had acquired.
Interpretation:	Interpretation	Knowledge goals: The student has knowledge about methods for simple interpretation.	Students used their learning goals as evaluation tools when discussing other students' games – for example, what three facts he/she had learned from other students' creations and if the story had a beginning, a middle and an end.
IT and communication		Skill goals: The student can use IT for everyday communication.	Students created digital learning games that taught their fellow students about facts using language as a tool in this process.
		Knowledge goals: The student has knowledge about recipient and sender relations in digital communication.	In the teams discussions, students were very focused on how to formulate, disseminate and evaluate new knowledge in their games for their fellow students.

Table 3. Excerpt of relevant simplified common goals in Danish for second grade when developing digital games for learning.

6. DISCUSSION

The excerpt of analysis presented in Table 3, performed following an informed grounded theory approach (Thornberg, 2012), was based on the signs of learning observed in the various individual, collaborative and constructivist learning processes described in sections 5.1–5.7. Another approach to the analysis could have been to focus on and follow each Specific Learning Goal (SCG) down through all the students' learning processes to demonstrate how each specific learning goal was reached through specific learning processes. However, this approach would have made it difficult to understand the actual overall progression of the students' game development and various learning processes and was therefore not chosen. In this case study, the problem-based and fairly open pedagogical approach adopted steered free of the phenomenon of students merely copying the teacher's shown example and thereby staying at a 'local minimum': for an example of this, see the 'keychain syndrome' (Blikstein, 2013). The student teams' complex endeavours helped them to succeed in reaching the learning goals for the class. While this investigation focused on how mother tongue language learning can benefit from a game development approach, findings from previous research (Weitze, 2016b) suggest that other subject matter areas can also benefit. As a sign of the students embracing this way of learning, the teacher reported that the students asked to pursue subsequent Danish language assignments using educational game development with Scratch.

7. CONCLUSIONS

This article has described an exploratory investigation into how learning through game development can contribute to students' academic learning and, specifically, how the application of educational game development as a teaching method can help in achieving SGC subject-specific learning goals in Danish for second grade students in a Danish primary school. SCG in Danish for second grade involve working with reading, interpretation, interactive communication and production processes and the use of language as a tool. The overall learning design for the class included problem-based assignments that supported the students in constructing digital games for learning with the Scratch game development tool. Use of the described learning design (Table 1) for the experiment, in combination with the tool developed for implementing and evaluating signs of learning (Table 2) for the chosen SCGs, made it possible for the teacher to link game development as a learning process with specific learning goals. According to the analysis, the students were able to reach the specific learning goals (SCGs) through their game development process. This took place in individual, collaborative and constructionist learning processes as they solved the complex problem of developing digital games for learning for their fellow students, which would enable those students to learn and be evaluated by playing the games.

Though the teachers and researcher viewed this experiment as a success, there is no doubt that this type of learning design needs to be 'orchestrated' and facilitated with great care. Furthermore, the complex and iterative nature of building digital games for learning, with its implementation of learning and evaluation situations, trial and error processes and debugging, proves a demanding process for both students and teachers. That said, learning through game development was seen as having great potential for the students as a new, motivating way of learning that leads to deep formal learning processes. Future work will involve developing user-friendly guides for teachers to work with this teaching and learning approach.

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