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Student Learning-Game Designs: Emerging Learning Trajectories

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Abstract: This article presents new knowledge about how students can implement learning and game elements into analogue and digital learning games as a means of learning and teaching curriculum-based subject matter. The purpose of the analysis is to identify what learning-game design elements were used in four learning games created by students, to investigate how these elements were employed, to determine what learning trajectories emerged in the two digital game tools and to offer reflections and suggestions regarding the learning processes students experienced when building the various learning trajectories for specific learning goals into the digital games. The article examines how specific features in the two digital game tools, Scratch and RGBMaker, afford creation of learning trajectories in various ways, enabling deep learning and gameplay processes for the players of the games. According to the study, the level of complexity of the built-in learning trajectories in the games was mirrored in the cognitive complexity of the student game designers' learning processes. The article presents four student-created games that demonstrate a progression in the depth of potential learning experiences. The student learning-game designers re-interpreted and used the conceptualised game-mechanics in the game tools to create complex learning trajectories and engaging gameplay. The analysis can be used to guide teachers on what learning-game design processes and elements should be supported in order to facilitate deep learning in this teaching and learning approach. The design-based research project used qualitative research methods; this included audio- and videotaped utterances and observations of the teachers and students as well as analysis of the students' paper prototype and digital learning games. Teachers and adult students from a full-time upper secondary general education program at VUC Storstrøm participated in co-design workshops through two iterations.

Keywords: Learning Design, Students as learning game designers, Scratch & RGBMaker, constructionism, students as learning designers.

1. Introduction

A growing body of research addresses the extension of game-based learning – be it the use of simulations, virtual worlds or games developed with the purpose of learning – to include the *creation* of games for learning (Earp, 2015; Kafai and Burke, 2015; Whitton, 2014; Weitze, 2015). When students create games for learning, they take a more active role as game designers instead of a less active role as game players (Oygardslia, 2015, Weitze, 2015). The creation of games as a means of learning originates from a constructionist pedagogical approach. Constructionism builds upon the thesis that there is a strong connection between design and learning. When students design digital learning games, the activities involve making, building, and programming – all processes that provide a rich context for learning (Harel and Papert, 1991; Kafai and Resnick, 1996; Weitze, 2016a). The game designer needs to think about the meta-structures in the game (Earp, 2015). This involves the interactions and game mechanics (what the player can do in the game) and how the designer sets the learning design into play in the game (Weitze, 2016c).

The educational focus in game design as a means of learning has primarily been on developing students' programming and computational thinking skills (Brennan and Resnick, 2012). Attaining specific curriculum learning goals in these creative programming processes is seldom an expressed expectation of teachers (Kafai and Burke, 2015, p. 323). The original goal of constructionism was to learn by designing (and for example programming) and, along the way, to achieve conceptual understanding of subjects such as mathematics and science (Harel and Papert, 1991). But how should the learning situation be designed if students are to reach specific curriculum-based learning goals?

1.1 Background and purpose of this study

The purpose of the current experiments was to create a learning design that facilitated the learning process for students by letting them be their own learning designers. Students designed their own digital learning games with the purpose of achieving specific learning goals from cross-disciplinary subject matters. The term *learning design* describes how a teacher shapes social processes and creates conditions for learning; it also describes the phenomenon of the individual student constantly re-creating or redesigning information in his or her own meaning-creating processes (Selander and Kress, 2012, p. 2; Laurillard, 2012). The teachers acted as learning designers for the students in this experiment. But the students were also their own learning designers, as well

as their peers' learning designers, as they discussed the subject matter, located content and conscientiously negotiated how to implement learning into small digital games for their classmates – the future players/learners of their digital games – to learn (Weitze, 2015).

The main focus of the research process was to create innovative, effective and engaging learning designs for students. As expected, the students learned by building the games while creating learning situations and building learning content into these games. According to the teachers' formative assessments, the students reached their learning goals at a cognitively complex level of understanding – they could explain, discuss and critically think about the concepts from the curriculum (Anderson and Krathwohl, 2001; Weitze, 2015, 2016a).

Students' learning processes were particularly influenced by the quality and characteristics of the learning situations built into the games. (Weitze, 2014, 2016a). It is therefore valuable to study which learning-game design processes and elements should be supported in order to facilitate deep curriculum learning. This study therefore investigated the characteristics and learning trajectories in those games where students succeeded in creating learning events, and it investigated how learning situations and learning trajectories were built into the games by the students. The study also investigated how the affordances of the game design tools facilitated the creation of learning trajectories that enabled deep learning processes for both the student learning-game designers and the players. This article describes the study's second iteration, which was successful in that most students developed digital games that went beyond simple quiz games.

2. Methodology

The investigation was conducted as a design-based research (DBR) study in which teachers and students were important co-designers in the development and testing process. The study used mixed methods. The data included field notes, audio- and videotaped actions and utterances, observations from the workshops, semi-structured interviews with teachers after each workshop, semi-structured interviews with students after the final workshop, informal meetings, videos of students' games being discussed and playtested, the student-created digital games, evaluation documents written by the students and questionnaires. The analysis was performed by analysing the teachers' and students' utterances and the digital games, and by coding the transcribed data, using the qualitative research software NVivo and taking an informed grounded theory approach (Thornberg, 2012). The analysis was concept-driven (using concepts from the theory and previous empirical data to find themes in the data) and used data-driven coding (reading the data and searching for new phenomena which are not known from previous preconceptions of the subject) (Kvale 2009; Charmaz, 2006). The experiment was developed through two iterations from Spring 2014 to Spring 2015.

2.1 Research objective and research design

This article investigates how students created learning designs for specific learning goals in the form of analogue games that were subsequently transformed into digital games, and what learning trajectories emerged inside these digital games. The participants included adult students (N=50) in two upper secondary general education program classes in VUC Storstrøm, an adult learning centre in Denmark. These students participated in a full-time course of study lasting two years. Game building was used as a means to reach learning goals from the curriculum. The experiments took place in two series of three student workshops lasting four to five hours each. In the first iteration of the study, the game concepts developed by the students failed to move beyond the "quiz game" level. This led to superficial learning processes (Weitze, 2014). The study continued by experimenting with the conceptualisation of what a *learning design* is inside a game and how to help students imagine *how to implement learning into a game beyond the quiz level* (Weitze, 2016b). The second iteration (Spring 2015) incorporated newly developed strategies to help teachers support students' learning processes in this teaching and learning approach (Weitze, 2015, 2016a). This iteration utilized a game design example developed in the game design tool Scratch (Scratch, 2016) and succeeded in helping students create more complex learning games and achieve deep learning processes.

The students were divided into teams in all iterations. Each team developed their learning game concepts by following instructions in an overall learning design. The aim for the overall learning design was to integrate areas of relevant academic subjects into small analogue games that then were transformed into digital games. This enabled students to become their own learning designers. Another aim was for students to become deeply involved in the learning process and content of the various subject matters to be learned. By examining and reflecting on the academic knowledge, students would become academically proficient. Instead of being "told" the academic knowledge, students would "do it themselves" – they would direct their own learning

trajectory and create learning games that could be played by their fellow students. This would enable the students to become the designers of their own learning through collaboration and discussion of ideas and possible solutions. In the second iteration, the students created the learning game designs in iterative processes, addressing and questioning the learning goals and the learning process in many ways. The learning goals were also addressed in the playtests that student teams carried out with other teams. The students brainstormed on creating game narratives that could encompass their chosen learning goals, and they documented their explicit learning goals for the games.

3. Learning game design approach

“Game design is a second-order design problem. A game designer designs the rules of the game directly but designs the player's experience only indirectly” (Salen and Zimmerman, 2004, p. 171). The same can be said about learning game design.

3.1 The Smiley Model

The Smiley Model is a learning game design model created for building engaging learning games (Weitze, 2016c). The model was used to inspire and scaffold the learning game design processes in the current learning design. The Smiley Model addresses how to design the learning process and how to implement learning elements into the game while also considering ways to make the game motivating and engaging. The Smiley Model uses a learning design framework that considers the following elements: designing for the students' prerequisites for learning, the setting or learning situation, the learning goals, content selection, creation of relevant learning processes, and evaluation processes. Six game elements can be used to *set the learning design into play*: game goals, action space or narrative, rules, choices, challenges and feedback. Each of the learning elements and each of the game elements are intertwined. The Smiley Model addresses the need to design the learning process, to set the learning elements into play through traditional game-elements and to design for motivational factors. The analysis in this article will, however, not address the motivational factors from the model. In order to balance learning design and game design, the students were introduced to the Smiley Model operationalized as assignments in the overall learning design. The model supported and made the students aware of the need to implement learning and evaluation processes in their games and supported their “gamification” of these learning processes.

3.2 Game design tools

In this project, students used Scratch (Scratch, 2016) and RGBMaker (RGBMaker, 2016) as digital game design tools. Scratch is a game editor that uses a block-based programming language and can be used to create interactive stories, games and animations. In Scratch, it is possible to share creations with others in an online community. Scratch has 77 stack blocks, equivalent to 77 various code commands, including extensions (Scratch Wiki, 2016); they are presented in the 10 categories in the block palette. The Scratch designer can make scripts by coding/connecting blocks shaped like puzzle pieces. RGBMaker has more comprehensive “ready-made” game mechanics built in; for example, levels are built in as an option for the game designer. These features can make it easier to create various game-mechanics in the learning game. Scratch can be regarded as a more open game design tool. It allows the designer to use his or her imagination freely when creating learning trajectories through the game design. In the overall learning design for the classes, the intention with the assignments was to strike a balance between allowing students the freedom to ideate and create analogue learning game prototypes without being limited by the affordances of the digital game design tool and introducing students to basic assignments in the game design tool so they are able to transform the analogue games into digital games.

4. Analysis of four learning games

The following is an analysis of the learning trajectories inside four digital games created by student teams in the second iteration. The purpose of the analysis is to investigate what learning game design elements were used in the students' learning games, how these elements were employed, what learning trajectories emerged in the two different digital game tools and, finally, to reflect on what learning processes the students in the teams have experienced by building the various learning-trajectories into the games.

4.1 Learning design areas for the four games – what was common and what varied?

The Smiley Model analysis of the designs of the four learning games revealed that their learning elements had three learning design areas in common: 1) **Prerequisites for learning**: In one sense, the prerequisites for learning for the games' audience – the students – were the same, as students participated in the same class;

but as adult students coming from various backgrounds, their prerequisites also varied. 2) **Setting:** The setting for the learning design consisted of analogue learning games that were subsequently transformed into digital learning games. 3) **Learning goals:** The learning goals for the students creating the games (and therefore also the learning goals for the games) were the same. They focussed on History and English as second language and were about the American Civil War and human rights. The remaining elements from the Smiley Model were presented in various ways in the four games. **Content:** the content is what the learning designer chooses to introduce students to in order for them to reach their learning goal. The learning content was different in the various games; this reflects the problem-based pedagogical approach, which allowed the teams to choose and create their individual learning situations and learning trajectories inside their games. The chosen content contributed to the learning situations created in the individual games. In the following sections, the games are presented in advancing complexity, from Game One to Game Four.

4.2 Game One – Quiz game

The first team created a quiz game in spite of the assignment – *not* to design a quiz game. The game presented a series of four questions. The students in this team, according to the teachers, generally were challenged, and the teachers reckoned that it was better to have designed a quiz game than no game at all. The students and the teachers reported that the students creating this game learned much more than they normally would have learned; one student said, “What we have learned by creating this game I will remember to a much greater extent than what we traditionally learn in these lessons.” According to the interview with the students, this improvement was the result of this particular teaching and learning approach, where they worked in much more depth and were responsible for developing a game on their own for their classmates. It must be noted that students also spent more time on the subject matter than they would have in a more traditional teaching and learning approach.



Figure 1: Game One digital interface (top) and map of possible learning trajectory (bottom).

Using the Smiley Model framework, the analysis of Game One revealed the following. **Learning processes:** As it was a quiz game, there was no possibility of learning from anything other than trial and error in the game. If the player (fellow student) knew the answer in advance from previous lessons, this game could be regarded as a test of knowledge; otherwise, students could play the game by guessing. **Evaluation:** The game gave summative feedback on whether the question was answered correctly or not. With regard to the **game elements**, the **game goal** was to answer all answers correctly and thus was equivalent to the learning goal. The **action space** or narrative was a still picture in the Scratch game interface, with various questions asked by Abraham Lincoln, who was depicted on a map presenting the northern and southern states in the US (Figure 1). **Rules:** If the player answered the questions correctly, he or she would pass on to the next question; otherwise, the player had to start all over again. **Choices:** The player could choose between two answers to the current question. **Challenges:** The player had to know the correct answers (or guess); the player could not

learn in the game. **Feedback:** The game gave immediate feedback when the player answered the question. The feedback was formulated in a humorous way, contributing to a light atmosphere directed at the adult audience. The game did not, however, provide helpful information – for example, explaining why an answer was right or wrong and using this opportunity to teach the player. When building learning into this game, the students had to investigate and choose what relevant knowledge about the American Civil War and human rights their fellow students should learn. They therefore learned by investigating this historical period and by formulating and building in matching questions and answers.

4.3 Game Two – Information presentation and quiz game

In the second game, the team started out by creating a big analogue prototype (Figure 2a). They used the prototype to create and discuss their ideas on how to build the game and how to implement learning possibilities into the game. The team created learning activities by “placing information” at various objects in the game. They used pictures of original objects from the historical period for the learning situations in the game. By clicking the objects in the digital game (Scratch), the player/learner was introduced to knowledge about human rights and the Civil War. In order to go to the next level, the player/learner had to be able to remember this information and answer the game questions. The game had a brief storyline ending with the game character being freed.

Analysis of the game design elements revealed the following. **Learning process:** The game presented pictures of original historical artefacts which, when pressed, offered the player knowledge about the period. The objects and the information did not always have a logical connection, however (Figure 2b). **Evaluation:** The player/learner was summatively evaluated by being asked to give the correct answer to a question about something he or she had learned about in the game. **Game goal:** The goal was not known in advance; therefore, the implicit goal was to finish the game. **Action space:** The scene in the digital game encompassed authentic pictures of objects from the historical period. Therefore, the player/learner also implicitly learned about the environment and living conditions in this period. **Rules:** If the player/learner answered the question correctly, he or she would pass on to the next question/level; otherwise, he or she had to start over again (Figure 2c). **Choice:** There were not many choices; in order to go on in the game, the player/learner had to remember information and supply the correct answer. **Challenge:** The challenge was to remember the correct answer based on information previously introduced in the game. **Feedback:** The game gave immediate feedback when the player answered a question. The player could revisit the information if the answer was wrong, learning in the process, and then try again.

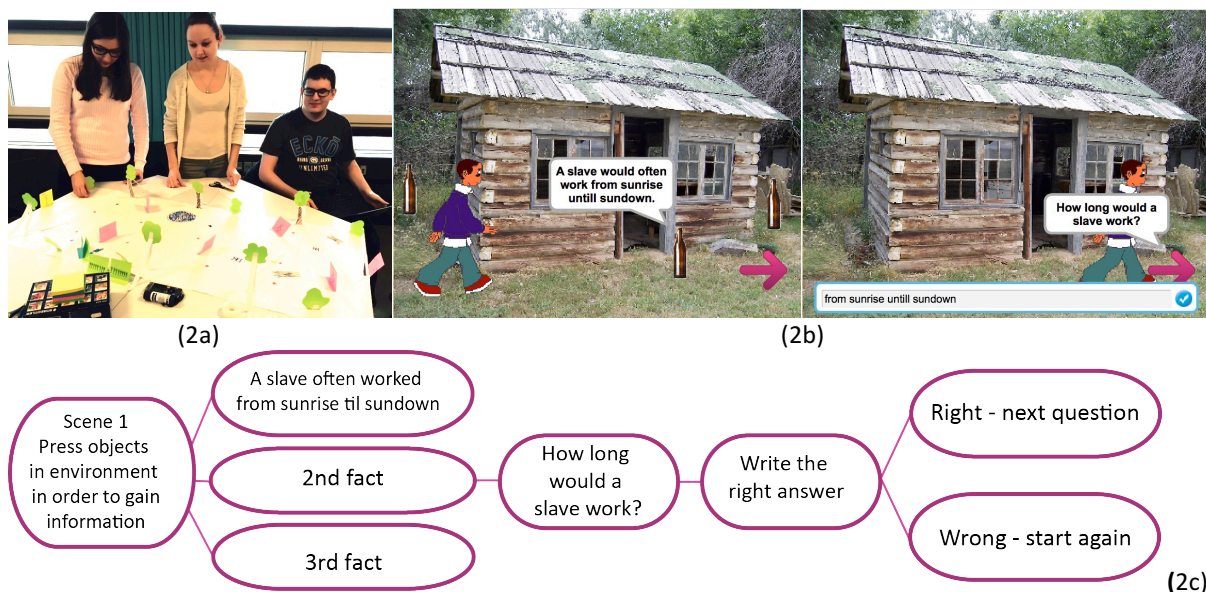


Figure 2: Game Two analogue prototype (a), digital interface (b) and map of possible learning trajectory (c).

In creating this game, students had many discussions about how to create learning situations in the game and how to integrate information about the historical period and events concerning human rights and the Civil War. Though this game in some respects was still a quiz game, it also presented information – teaching the player facts that had to be remembered in order to progress. For each question the student game designers

asked in the game, they had to find three facts to teach the player. They also had many discussions on how to create an authentic storyline in spite of the simple game structure. According to the teachers, the students achieved a deeper understanding of the subject matter than they normally would have achieved.

4.4 Game Three – Learning by experience

This game’s storyline encompassed a chronological overview of historical events from the American Civil War. Students reported that they created the storyline by trying to investigate backwards through history – starting with the end of the war and then seeking to determine why certain actions had been taken by either the North (Lincoln) or the South (Davis). By working backward and forward in the chronology of events, the team mapped out causal connections between various events. The specific learning trajectory for their game was that the learner/player would choose to be a soldier in either the southern or northern states and would learn through experience and consequences in the game. The player would be able to make authentic historical decisions and then experience the consequences. For example, as a soldier in the South, a player would participate in a particular action against the North and experience what the North chose to do in response.

All of the students were introduced to game design as a means of learning in the overall learning design. Some of the first assignments in the gamified overall learning design for the class involved creating small exercises in the game design tool Scratch in order to become familiar with its features and affordances. According to teachers, the team that created Game Three experienced a very deep and comprehensive learning experience while they discussed their game with each other and with the teacher. Their deep learning process, however, mainly took place in the analogue game construction process (Figure 3). Because they found the initial assignments in the game design tool simple, they assumed they would have an easy time transforming the analogue game into a digital game. As it turned out, this was a very difficult process. The students lacked the necessary programming skills (stemming from not using their time to learn what was suggested in that area), but their difficulty was perhaps to a larger extent due to the fact that they had not thought out their rules for the game in detail. This made it difficult for them to construct the digital game. According to Salen and Zimmerman, “If you can plot out the rules of the games you are one step closer to being able to describe specifications for a programmable prototype” (2004, p. 148). By creating more specific rules, the students would have had to think out and construct the mechanics behind the choices and consequences in the game.

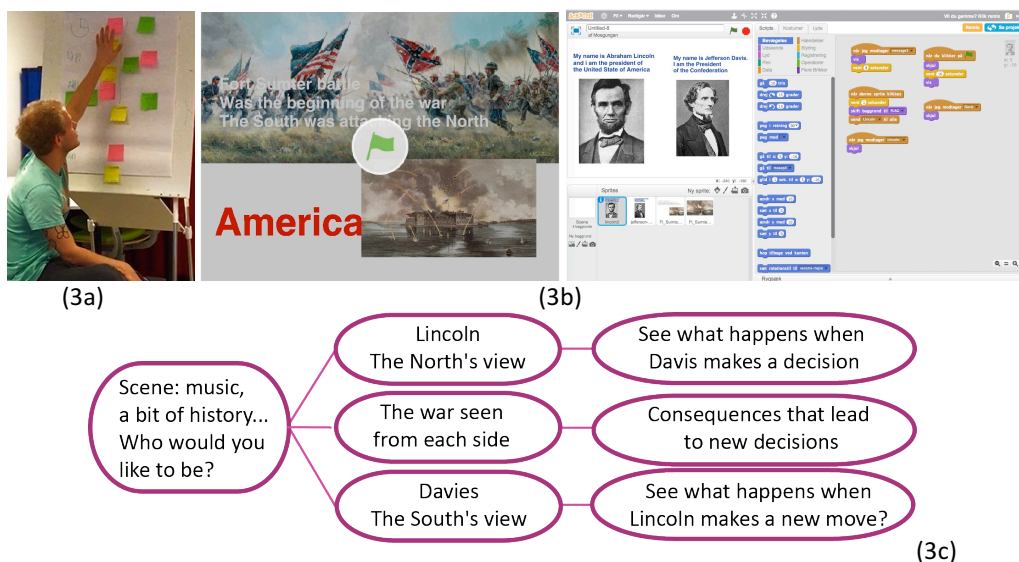


Figure 3: Game Three analogue prototype (a), digital interface (b) and map of (im)possible learning trajectory (c).

In Game Three, the analysis of the game design for the analogue game revealed the following. **Learning processes:** The learner/player could choose between two positions and, by acting in the game, could learn through the historical consequences of various actions taken in the war. **Evaluation:** The students did not have a plan for evaluating players’ knowledge in the game. Their game could, however, be seen as an example of learning by experience. **Game goal:** To participate in the war to the end. **Action space:** Various relevant still pictures and sounds, with choices and consequences written in text. **Rules:** The discussions among the students in the team revealed that students intended to illustrate the historical determining choices and their

consequences (loss of soldier lives and loss of health for the soldier-characters in the game). The rules and game mechanics were not developed in detail or implemented in the digital game. The students had used a lot of energy unravelling and exploring what events took place and why. Though they assured us several times that it would be easy to transform into a digital game, this was not how it turned out, a fact that frustrated them. They did not use any time to experiment with rules and detailed game mechanics until the very end, and this was too late. **Choice:** This game let the player/learner choose to be a soldier from the North or the South.

By creating a game with this comprehensive information, going beyond a quiz game in the game mechanics, the students developed a deep knowledge about the subject matter. As one of the students said, “We have learned by building the game, because we have investigated it so thoroughly and repeated it so many times. So actually it is not the students playing it that will learn the most, it is the students that are creating the game – they will remember it ... for good, I think!” The teacher was very satisfied with their learning process as well: “It’s one thing to be able to remember a date – like in Trivial Pursuit [a quiz game]. But we are interested in *why* it happens in history, the causal explanations – why does the event take place, in whose interest and so on. Here the creation of games as a means of learning is very well chosen.” In this third game, the students learned a great deal while constructing the storyline and game design for their analogue prototype. Their difficulty in turning the game into a digital game, however, calls for reflection on how to support and guide future students’ game design processes in order to maintain a balance between the complexity of the learning game they want to create and their abilities to transform it into a digital game.

4.5 Game Four – Authentic storylines, learning opportunities and stealth assessment

The fourth student game design team chose another game design tool: RGBMaker. The affordances of this game design tool, as well as the hard work the students put into the design process, led to the creation of a more advanced digital learning game than the previous three games. The learning trajectory in this game was much more complex and made it possible to learn in various ways while playing the game (Figures 4, 5).

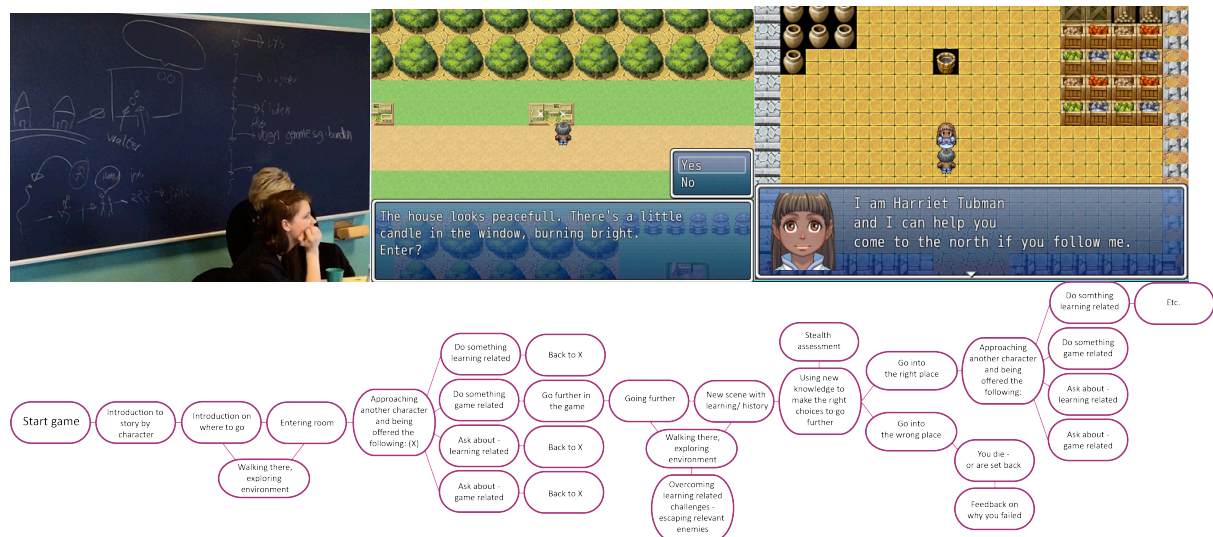


Figure 4: Game Four analogue prototype, digital interface (top) and map of the possible learning trajectory (bottom). A larger version is available following the references (Figure 5).

Analysis of the learning game design: The player was represented by a character in the game, and the **learning process** took place through the character's experiences. **Action space:** The character in the game, an enslaved person in the U.S. before the Civil War, was finally helped to flee, experiencing various historical events on his way through the story. The player had several opportunities to become emotionally engaged in the scenes in the game. RGBMaker's game tools made it possible for the character to introduce the story to the player. **Choice:** The player could explore the game and choose to enter various areas. The player could approach other game characters, choosing to do or ask something learning-related (historical) or game-related (game-play). When choosing between these possibilities, the consequences (**rules**) were equivalent to the historical consequences. This allowed the player to learn as he or she played (learning by doing). **Evaluation:** The game character met other characters along the way who gave hints about where to go and what to do. If the character followed these (authentic historical) suggestions, the player could move on in the game, and these

opportunities worked as examples of stealth assessment (Shute, 2011). **Challenges:** The student game designers used the affordances of the game tool; for example, they interpreted/used an inherent game mechanic in the game-tool (escaping enemies) as part of the original story, in which the enslaved character tried to avoid being caught while fleeing. **Feedback:** If the character made the wrong choices or was caught, he or she would be sent back. The **game goal**, revealed through the game, is to become free, and when the character succeeds in doing this, he or she meets another character who reads the Emancipation Proclamation. This game succeeded in using both the learning and game elements in a more engaging way than the three previous games did.

RGBMaker and the fourth team's thoughtful use of this game design tool made it possible to create more complex and playful learning trajectories in this game. Though it was still a rather simple game design tool, RGBMaker allowed students to implement a range of different learning opportunities in this game. Creating various learning opportunities (exemplified in the map in figure 4 and 5) also made the student game designers' investigations of the subject matter and the creation of authentic storylines, learning opportunities and stealth assessment in the game much more demanding (but also very engaging). That is, in contrast to the creation of a simple quiz game, this more complex game design, according to the teachers and students, demanded searching, finding, reflecting on, implementing and evaluating larger amounts of information about the subject matter and the learning goals; as well as more nuanced game design processes. This contributed to a much deeper learning process for these student learning-game designers.

5. Balance in learning game design as a means of learning and student reception

When planning to let students learn by creating learning games, the teacher has to consider how to maintain a balance between the subject-matter knowledge required by the curriculum and the skills needed for computational thinking and learning game design. In this project, the development of students' computational thinking skills and coding ability was not a goal in itself. The goal was to learn the cross-disciplinary subject matter, and according to the teachers and the students themselves, most of the students learned at least as much as they would have in more traditional teaching and learning approaches. Most students considered game design as a means of learning a welcome and inspiring approach, although some students preferred to stay in the analogue phase of learning-game design. A few students found the complexity of creating learning games and turning those games into digital games frustrating and meaningless, as this was not part of the established curriculum (History and English as second language).

5.1 Discussion and Conclusion

In this experiment, adult students in an upper secondary general education program class succeeded in achieving curriculum-based learning goals by using learning-game design as a means of learning. Four teams of students implemented learning elements, created learning situations and learning trajectories and set these elements into play in small digital games. Equivalent with what the teachers and students told they had experienced when interviewed, the analysis of the various learning and game elements in the four games suggests that the creation of more complex learning trajectories in the games results in more cognitively complex learning processes for the student learning-game designers. For example, in the simplest quiz game, the student designers only had to create simple questions and answers, whereas in the complex games, the students created curriculum-based storylines, a variety of in-game learning situations and even implicit ways that the learner/player would be assessed in the game. These more complex learning situations involved deep work and deep investigation of the subject matter to be learned. The students who used the game design tool RGBMaker had to work harder to learn to code in the tool, but RGBMaker featured built-in affordances that, when used in a thoughtful way, supported and inspired the students to build complex learning trajectories and thereby experience complex learning processes as well as gameplay processes. The open game design tool Scratch has many advantages and can be used to take multiple creative directions. The students using Scratch did not progress as far in the learning-game design process; their challenge was that they to a larger extent themselves had to invent and develop more complex learning trajectories in the game design tool. Inspired by the results of this experiment, future experiments will focus on creating multiple Scratch game-mechanic examples with more relevant and complex learning trajectories in order to guide, inspire and support students to build more complex learning processes when designing games as a means of learning.

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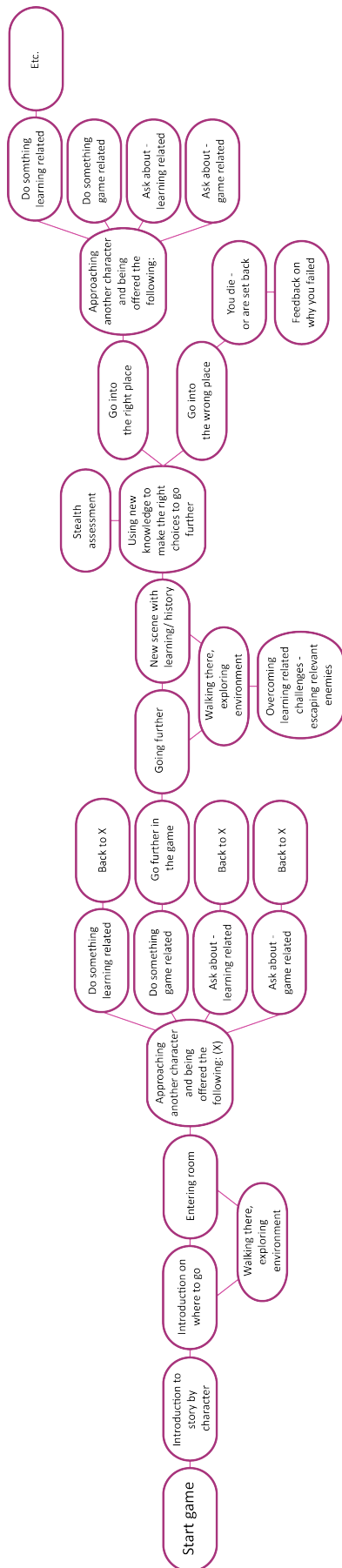


Figure 5: Game Four - map of the possible learning trajectory