How Student Game Designers Design Learning into Games

Weitze, Charlotte Lærke

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Author: Charlotte Lærke Weitze

Abstract: This investigation examined how to support students in creating learning designs for specific learning goals in analogue and digital games as a means of learning. The study also explored the learning trajectories that emerged in the digital games created by the student learning-game designers. The DBR study was developed through three iterations over two years, involving teachers and students in co-design processes. Together with the teachers, an overall learning design supported the learning process for students by inviting them to be their own learning designers as they designed digital learning games for specific learning goals in cross-disciplinary subject matters. The findings were that the students succeeded in developing and implementing specific learning goals in their games. The students also developed learning trajectories through the games by designing various learning and evaluation opportunities for the player/learner playing the game.

Keywords: Students as learning game designers, learning game design, game design models, constructionism, PBL, students as learning designers.

Introduction

Educators and educational theorists have long advocated for learning games as an active way of learning by experience. If carefully designed, learning games can allow learners to interact with learning situations that cannot be replicated in a traditional classroom setting (Barab & Dede, 2007; Squire, 2011; Gee, 2003). Kafai and Burke (2015) argue that there may be a valid alternative to the serious game movement's debate over whether the educational potential of games is realised through commercial games or skill-and-drill exercise games. Perhaps the debate should instead be between the practice of *playing* games and the practice of *making* games. There is a growing body of research on extending game-based learning—be it the use of simulations, virtual worlds, or games developed with the purpose of learning—to creation of games as a means of learning (Earp, 2015; Kafai & Burke, 2015; Weitze, 2015). Instead of giving the student a less active role as game player, creating games as a means of learning positions the student in a more active role as game designer (Oygardslia, 2015, Weitze, 2015).

Learning-game creation as a means of learning originates in a constructionist pedagogical approach. Constructionism builds upon the thesis that there is a strong connection between designing and learning. When students design learning games, the activities involve making, building, and programming, all of which provide a rich context for learning (Harel & Papert, 1991; Kafai & Resnick, 1996; Weitze, 2016). The learning-game designer needs to think about the meta-structures in the game (Earp, 2015). This involves interactions and game mechanics (what you can do in the game) as well as how the game's learning design is set into play. When using game design as a means of learning, the focus is often on learning to programme and develop computational thinking skills (Brennan & Resnick, 2012); teachers seldom have an expressed expectation that students must attain specific learning goals. The generally accepted notion is that "conceptual understanding of subjects such as mathematics and science, as well as the dynamics of teamwork and task prioritization, are not learned as ends in and of themselves but put expressly toward the purpose of creating genuinely playable games, resulting in more genuine—and collaborative—learning experiences" (Kafai & Burke, 2015, p. 323).

In contrast, the purpose of the current experiments was for students to incorporate specific learning goals in the process of creating their own learning games. The aim was to create an overall learning design which would facilitate the students' learning process by letting them be their own learning designers. In designing their own digital learning games to achieve specific learning goals in cross-disciplinary subject areas, students would themselves attain specific learning goals in those subjects. The term *learning design* describes 1) how a teacher shapes social processes and creates conditions for learning and 2) the phenomenon of the individual student constantly re-creating or redesigning information in his or her own meaning-creating processes (Selander & Kress, 2012, p. 2). In this experiment, the teacher was the primary learning designer. But the students were also their own learning designers, as well as their peers' learning designers: they discussed the subject matter, found content, and conscientiously negotiated how to implement learning into the small digital games they were creating in order for future players/learners to learn (Weitze, 2015).

The main focus of the research process was on creating innovative and engaging learning designs for students. As expected, the students learned the most while designing learning games as they created learning situations and built learning content into these games. According to the teachers' formative assessments, the students reached their learning goals: they could explain, discuss, and critically think about the concepts from the curriculum, confirming that they had reached a complex level of understanding (Weitze, 2015, 2016). The quality and characteristics of the learning situations built into the games were found to be important for the depth of the students' learning processes. Therefore, the following research questions were relevant to investigate in this study: How can students be supported to create a learning design for specific learning goals in analogue and digital games as a means of learning? What learning trajectories emerge in those digital games that succeed in creating learning events?

Methodology and Research Design

Approach, Data Collection and Analysis: The investigation was conducted as a design-based research (DBR) study through three iterations over two years (Spring 2014 to Spring 2015). The teachers and students were co-designers in the development and testing process. The study used mixed methods. Semi-structured interviews were conducted with teachers after each workshop, and semi-structured interviews were conducted with students after the final workshop. All workshops were observed, and actions and utterances were audio- and videotaped. Data included field notes, evaluation documents written by the students, videos of students' games being discussed and playtested, and the students' digital games themselves. The analysis was made by coding the transcribed data using the qualitative research software NVivo with an informed grounded theory approach. This was carried out as concept-driven coding (using concepts from the theory and previous empirical data to find themes in the data) and data-driven coding (reading the data and searching for new phenomena which are not known from previous preconceptions of the subject)

Participants and Setting: The audience in the main iterations (the first and third) were adult students from two upper secondary general education program classes at VUC Storstrøm, an adult learning centre in Denmark. These students participated in a full-time education program lasting two years; building games supported learning the curriculum. In the second (smaller) iteration, the participants included children in the 7th grade. In this class, students were studying *creative use of IT*, but the students still created the games for specific learning goals. The second iteration narrowed down to experimenting with a specific part of the overall learning design: the conceptualisation of what a *learning design* is and how to help students imagine *how to implement learning into a game beyond the quiz-level*.

Project Iteration	Period	Participants	Form	Subject matters	Pedagogical Approach: Constructionism & PBL	Game tool
1st iteration	Spring 2014	17 adult students, 3 teachers	3 student workshops, 4 hours, 1-week interval	History, religion, and social studies; fixed learning goals	Fixed overall learning goals. Part of the evaluation process. Students had already been introduced to the subject.	Game Salad
2nd iteration	Fall 2014	14 children in 7th grade, 1 teacher	1 student workshop, 2 hours	Own choice of subject matter and learning goals	Problem-based approach. Students chose subjects and found content themselves.	Scratch
3rd iteration	Spring 2015	19 adult students, 2 teachers	3 student workshops, 5 hours, 1-week interval	History, English as a second language, and source criticism; fixed learning goals	Fixed overall learning goals. Problem-based approach. Students had to find information about the subject during game development, learning in that process.	Scratch & RGB maker

Table 1: The three iterations in the project.

Workshops: All of the students and teachers were new to game design. Each team developed their learning-game concepts by following the instructions in an overall learning design. The students brainstormed to create game narratives that could encompass their chosen learning goals, and they documented their explicit learning goals for the game. The aim for the overall learning design was to let the students integrate aspects of relevant academic subjects into small analogue games that they then transformed into digital games, enabling them to become deeply involved in the learning process and content of the various subject matters to be learned. In examining the academic knowledge, they would become reflective about the academic knowledge; as a result, they would become academically proficient themselves.

The students were divided into teams in all iterations. The purpose was for students to 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, discussing ideas and possible solutions. The students created the learning and game designs in iterative processes. Therefore, the learning goals and the learning process were addressed and questioned in many ways. The learning goals were further addressed in the playtests that student teams carried out with other teams. Details about the iterations are listed in Table 1.

Empirical and Theoretical Findings

The following is an analysis of how the students were supported and inspired to implement specific learning goals into the digital games. It was found that qualifying how to implement learning into the games was a means to create deeper learning processes for the students (Weitze, 2016).

Imagining the Unknown – First Iteration

In the first iteration (Spring 2014), the adult students had to describe several aspects of their learning design in writing before building the games. The intent behind making the learning design very explicit to students was to scaffold them through a learning process and also to support the teachers who were new to this kind of gamified learning design. The questions were inspired by Hiim and Hippe's learning design model (1997), which encompasses learners' prerequisites for learning, setting (learning situation), learning goals, content, learning processes, and evaluations. Even if students understood the learning design only on an implicit level, this could be detected when analysing their answers. The results of the first iteration revealed that students had difficulties in understanding learning design concepts and therefore also had difficulties in describing the learning design for the game (learning goals, learning activities, learning process, evaluation, etc.). This resulted in the students' becoming superficial in their learning design approach.

The research results from the first iteration showed that the inexperienced students and teachers had difficulties in imagining a mental model for how to build a learning game that enabled learning above the *remembrance level* of cognitive complexity. Almost all games became quiz-games. An analysis of the questions posed in the games revealed that the composed questions were either 1) exactly consistent with what the students had learned in the previous lessons (and therefore could only be answered if the player knew the exact answer in advance) or 2) common knowledge—questions most people would be able to answer. The learning implemented in the students' games showed signs of facilitating learning processes only on the cognitive complexity level of remembering. Other cognitive complexity levels were neglected, such as understanding, applying, analysing, evaluating, or creating—both for the learning designers themselves and for the players/learners of their games (Anderson & Krathwohl, 2001, pp. 67–68). When evaluating the project's success the teachers asked for a learning game example in the actual game tool to help them imagine the possibilities for creating a learning game and implementing the learning goals. The analysis of the students' games suggested that the learning games would enable a deeper learning process by creating learning situations or scenes for a community of practice inside their small games. This made it possible for the students to compose learning trajectories for the characters in the game, using relevant content while learning in this process. Therefore, as one of the first elements in the overall learning game design, it is important to discuss context and narrative in the game, as they are the foundation for these learning situations.

Creating Supportive Artefacts for Students Learning by Designing Games

According to the findings in the first iteration, there was a need for an initial discussion with the students on learning design in general in order to qualify their knowledge and considerations about learning goals, learning processes, learning activities, and evaluation processes. There was also a need for an illustrative learning game example in the game tool. Therefore, two artefacts were

constructed as support: a simple learning game example, created in the relevant game design tool Scratch (2016); and a related mind-map which explained how the learning design was illustrated in the learning game example (an example of the game prototype can be found at http://scratch.mit.edu/projects/31359632/).

To help the students understand the concept of learning design, the second and third iteration began by introducing the small prototype learning game. After students were shown this small game, they were introduced to a mind-map (Fig. 1), which showed how the learning design concepts and the game were connected. The mind-map had two parallel tracks. One (yellow) told what part of the learning design was introduced in the game, and another (red) told what happened in the game at this point and also introduced questions to discuss.

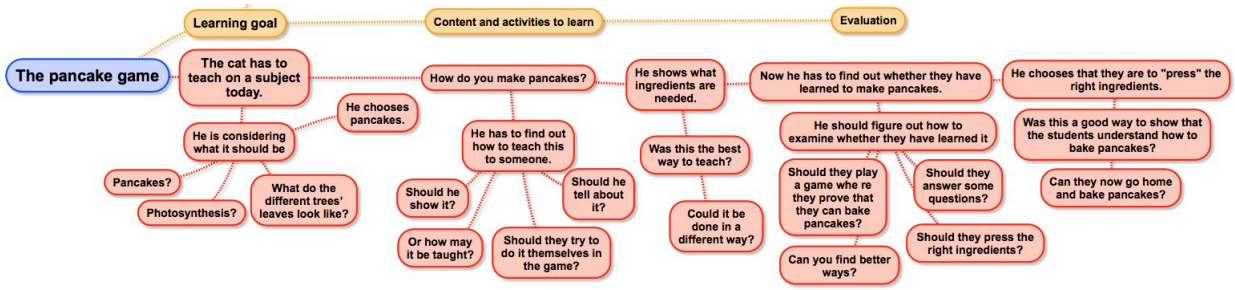

Figure 1: Mind-map illustrating and discussing the learning game example.

The purpose of the mind-map was to make the concepts of learning design clear and to discuss the learning goals, the learning activities, and the evaluation in the game. The learning process described in the mind-map was discussed with the students and compared with the game example. By discussing how the learning and the game were connected, the aim was to help the students start reflecting on how to design their own games to facilitate specific learning goals. As this particular example was a quite poor learning game, students were invited to contribute ideas for a way to make the game a better and deeper learning experience. As a result of using these artefacts (the digital game example and mind-map), teachers and students were discussing learning design concepts and how to implement learning goals in a learning game from the very start.

In the second iteration, students were directed to create games that would facilitate subject matter learning for future players/learners of their small games—that is, no quiz-games. Students also had to make sure to evaluate the facilitated learning by deciding if the player/learner would be evaluated on the game's subject matter *after* playing the game or while still *inside* the game. Finally, students were told that it would support learning processes in the game if they considered making the small game into a learning situation or a small community of practice; students were then allowed to reflect on how and why this should take place in their game. This process was equivalent to findings on how learning can be implemented in efficient learning games (Ramirez & Squire, 2015).

Choice, Development, and Implementation of Learning Goals

In the learning game example and mind-map, the learning goals were introduced and discussed: the character discussed *what* learning goal to choose (Figs. 2 and 3). This was intended to inspire the students to discuss the topic of what to teach and also to help them develop a mental model of what a learning goal is.

The 7th grade students in the second iteration could choose their own learning goals. Since this iteration investigated how to support a conceptual understanding of the learning design combined with the game design process, the goal was not to aim at a specific learning goal, and the teacher did not decide the area for the learning goals; students were free to choose their own. Their chosen goals ranged from "learning the concept of how to drive a car", "Learning the concept of prime numbers", and "how to start building a game in Scratch". Due to a lack of time, students did not finish their games. But analysing the partially-completed games and the learning processes taking place around them revealed that students had found information for their learning goals and had discussed those goals, and further, that students had already learned in this process. They had also designed a learning situation and narrative in their games, which, to a much larger extent than the first iteration, suggests that a deeper learning process took place both in and around the small games. The variety

in choice of learning goals for the games illustrated how students themselves imagined how the creation of learning games could be used as a means of learning various subject matters.

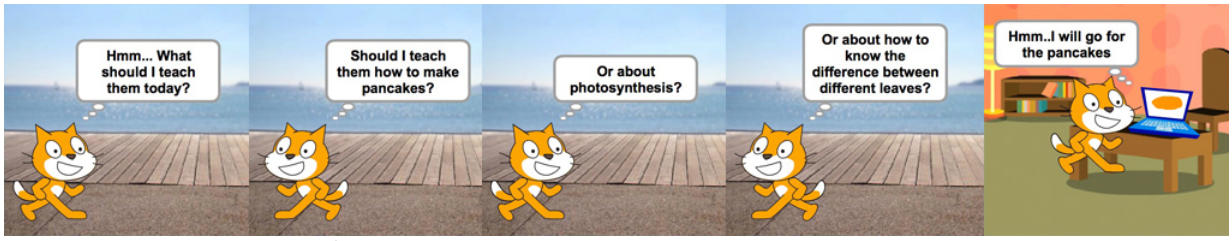

Figure 2: Character considering which learning goal to choose.

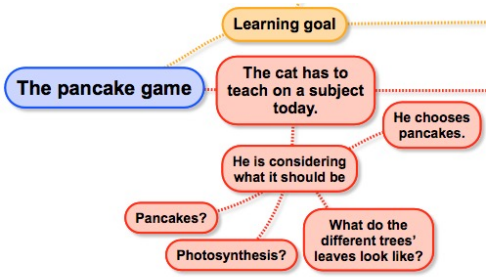

Figure 3: Mind-map describing and explaining what takes place in the game.

Creating Learning Activities in the Games

The adult students in the first and third iterations were assigned learning goals; however, they created their own variations of the learning goals and content for each game. As a result of the introduction and discussion of a learning game example, the adult students in the third iteration had a much easier time implementing their learning goals into learning situations in their games.

In the game example, the character and the mind-map (Fig. 1) illustrated how to teach the chosen subject, suggesting different approaches. This part of the example was also discussed with students and teachers in both the second and third iterations. The purpose of these artefacts (game example and mind-map) was to help the students create a mental model of what a learning situation could look like in a game and to inspire them to start imagining how to create a learning situation in their game. In the assignments for the second and third iterations, the student game designers were asked to describe 1) What does the player/learner learn by playing? 2) What can the characters do in the game? and 3) What does the character learn when doing things in the game?

Examples of Learning Activities and Learning Trajectories in the Digital Games

Inviting the player to be an apprentice: The students created teaching and learning trajectories for the non-human actors inside the small digital games, thereby creating them for the players outside the digital games as well. For example, in a math game, the 7th grade students created teaching conversations between two non-human actors in the roles of student and teacher. In another game that sought to teach players how to use the software program Scratch, questions and conversation were exchanged between the character and the player of the game. By creating these scenes, the students invited the non-human student as well as the player/learner to be a learner or apprentice.

Learning-by-doing: The students teaching math had planned a teaching section in the game that was to be followed by an interactive section in which the player/learner should be able to solve the kind of equations the students had just been taught. This would enable a learning-by-training or learning-by-doing in the game, with feedback for the player/learner. A learning-to-drive game also planned for an instructional section and a learning-by-doing section in which the player/learner had to "push the right pedals" in the game as a way of assessing his or her new knowledge. The type of knowledge facilitated through the games was both declarative knowledge (knowing *what*) and procedural knowledge (knowing *how*), and the acquisition of this knowledge made it possible for the players/learners to do things that they learned in the games.

The adult students developed four learning games in the third iteration of this gamified learning design. The students were specifically advised to create small learning situations in the games and to build the learning activities into the game mechanics, that is, what one can *do* in the game.

Learning by "clicking": One of the adult groups created learning activities by "placing information" at various objects in the game. The learning goals, and therefore the activities in the learning games, involved the themes of human rights and the American Civil War. One of the groups constructed a learning situation involving pictures of objects the students found in the Library of Congress Digital Collections (https://www.loc.gov/library/libarch-digital.html). When players/learners touched (clicked) these objects, they were introduced to information about human rights and the Civil War. The information was, however, not directly connected to these objects, and in the team-peer-review this missing connection was criticised and suggested improved. In order to proceed to the next level in the game, the player/learner had to be able to remember this information and write it down in the game.

Learning by experience: Students designed a learning game in which the player/learner was a character that embodied a person from history. By experiencing and perhaps identifying with this person's situation and experiences, the player/learner learned about the historical period and historical events. The character met other characters in the game and was continuously introduced to various choices when meeting other characters in specific contexts. These choices could, for instance, be different questions their character was given to ask other characters; or it could be something their character could choose to do in the game.

Learning from direct information: The answers to some questions provided information about the historical period and historical events relevant to this context in the learning situation in the game; whereas others simply added to the narrative with the purpose of engaging the player in the game.

Learning from authentic hints: Some answers explained how the historical person being played by the player/learner could overcome a challenge in the game world that related to challenges the character would have faced in the real world in that historical period. For example, a learner/player might be travelling on the Underground Railroad, which helped enslaved people flee from the South to the North. The game character would have to determine whether a house was a safe house, with people who would help them in this process. To create a playful atmosphere, the solution was not supplied directly, but only in hints, so the player/learner had to explore to overcome the challenge.

Learning through stealth assessment: Examples like the one just mentioned at the same time functioned as stealth assessment in the game, that is, the kind of assessment in learning games that happens as part of the story through real (game) world consequences (Shute, 2011). The player/learner had to find and learn this information in the game in order to meet the game challenge and move to the next level. The player/learner could choose which path to take in the game; however, specific pieces of knowledge (part of the learning goals) were needed to move on in the game.

Learning by consequence: This way of learning might involve a historical character asking an anachronistic (historically inappropriate) question, given the historical period and the characters' positions in the situation in the game. As a consequence, the character would then "die", and the learner/player would have to start over again. These consequences that were built into the game enabled the player/learner to learn about habits, human rights traditions, and culture from that period by playing the game.

Learning from just-in-time additional knowledge: One of the games was designed so that when the player/learner had completed a scene or learning situation, additional knowledge and information about that particular subject or period was presented as additional text moving over the interface like scrolling credits of a movie, providing more detailed information about the subject just introduced in the situation.

In some of the games, the students spent a long time creating engaging dialogues for the game characters; this contributed to the students' experience of being involved in the learning situation.

Conclusion

The article investigated the most effective ways to support students who are creating learning designs for curriculum-based learning goals in analogue and digital games as a means of learning. The article

also identified the various learning trajectories that emerged in the students' digital games. The finding from this DBR study's three iterations was that presentation and discussion of a learning game example in a relevant game design tool, combined with discussion of learning design concepts, supports students in deepening the learning processes in their learning games. Introducing and discussing the learning game example together with learning design concepts contributed to the students' creation of more complex learning games—above the level of quiz-games and the cognitive complexity level of remembrance.

When students followed the newly developed strategy, they succeeded in creating and implementing specific learning goals in their games. These strategies included presentation and discussion of two artefacts (a digital game example and a mind-map) in order to educate students about learning design concepts and teach them how to implement learning goals into a learning game. Students were directed that the games they designed should facilitate learning about the subject matter and that the facilitated learning should be evaluated. Finally, students were encouraged to create a learning situation in their game. The following learning trajectories or learning opportunities were designed into the games: inviting the player/learner to be an apprentice, learning by experience, learning from direct information, learning from just-in-time additional knowledge, learning from authentic hints, learning by consequence, learning through stealth assessment, learning and assessing by doing in the game.

Combined with knowledge from earlier research results (Weitze, 2016), the fact that the students succeeded in creating nuanced learning and evaluation processes inside the games contributed to cognitive complex learning processes for the student learning-game designers. Future experiments will involve the development of new learning-game examples involving these learning trajectories as inspiration for new student learning-game designers.

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