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Reflective, Creative and Computational Thinking Strategies Used When Students Learn Through Making Games

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Abstract: Since the 1980s, scholars have had visions about how computers can change how we think and learn and may support more engaging learning processes. Recently many countries have extended their formal school systems to teach students about computational thinking, with the aim to support children in mastering digital materials, becoming digital producers, and using technology to develop the ability to use their creativity and develop problem-based digital projects. One of the questions in this new area of formal educational is whether acquiring computational thinking (CT) skills should be a goal in itself—that is, a new subject matter in the curriculum—or whether CT should become part of cross-disciplinary projects in school. The basis for the current experiment is a longitudinal (four years), design-based research experiment, where CT was used as one of the means to reach learning goals in cross-disciplinary academic subjects. In the current part of the experiment, adult high school students (K–11) created digital learning games using the game design tool Scratch. The purpose was to teach their classmates about specific learning goals in geography, chemistry, biology, and social studies within their digital learnings games while they themselves learned about these subject matters through the learning game creation process. The findings were that game design and CT could be used as means to reach learning goals and spark reflections about cross-disciplinary academic subject matter and that the learning game construction process involved the students’ considerations about four central areas and processes within these areas. Also, as the students transformed their games from a vision to a concept and into a concrete digital object, they were challenged to become innovative and creative and were supported in their thinking and learning processes, developing knowledge about problem-based work and CT competencies.

Key words: Computational Thinking, Learning Game Design, Students as Learning Game Designers, Constructionism, Scratch.

1. Introduction
A major concern for educational institutions is how to design learning for students to help them develop skills that match 21st-century requirements. This demands that we know what skills should be developed, how we should teach and support the students’ learning processes, and what learning technologies could support the development of relevant individual and collaborative competencies. The strategy that many educational scholars suggest is to educate the students so that they become strong in problem-solving, critical thinking, innovation, and creativity, since this will give them the competencies to embrace and overcome the unknown future challenges they will face. But how do we teach these 21st-century skills?

1.1 The benefits of active learning
The philosopher and educational reformer John Dewey suggested the development of reflective thinking skills as the main goal of education. Thinking is the method of intelligent learning and is developed through experience: “trying to do something and having the thing perceptibly do something to one in return” (Dewey, 1956). This learning by doing approach correlates strongly with the constructionist pedagogical approach. In constructionism, a fundamental idea is that there is a strong connection between design and learning and that activity involving making, building, or programming provides a rich context for learning and building knowledge (Harel & Papert, 1991; Kafai & Resnick, 1996). Piaget's constructivism, which focuses on the students’ construction of meaning as a condition for learning, is taken further by Papert’s constructionism theory, which emphasizes that meaning in particular can be constructed by the creation of artefacts, often with the help of different types of digital media (Harel & Papert, 1991). The construction of these artefacts enables reflection and new ways of thinking based on the tools the students use alone as well as collaboratively, empowering the students to take charge of their own education (Harel & Papert, 1991; Kafai & Resnick, 1996). Learning and creative development happens when the material “talks back” to the students in unexpected ways during the development process (Schön, 1992). But what elements do the thinking and learning processes require?
According to John Dewey’s pragmatic world view, there is a close relation between the following elements in students’ ongoing reflective process; they 1) experience and perceive a difficulty or problem; 2) localize, analyze, and define the problem; 3) use spontaneous and innovative ideas as hypotheses for solutions to the problem; 4) reflect and elaborate ideas and consideration of facts around the problem; and 5) employ tests and interventions followed by evaluation of the suggested ideas, concepts, or solutions to the problem. If this leads to a satisfying result and thereby valuable new knowledge, the process ends; otherwise, the student starts again, armed with his or her new insight (Figure 1). These linked processes of reflection and experimentation are common ways to approach and solve problems in everyday life (Dewey, 1910, p. 72). But how is this turned into a pedagogical approach?

**Figure 1:** Experience and experiments creating knowledge in everyday life (based on Dewey, 1910)

The problem-based learning (PBL) pedagogical approach is a “learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem” (Savery, 2015, p. 5). PBL is strongly inspired by the elements in Dewey’s reflective process. In PBL, the students find, or are introduced to, ill-structured, complex (yet meaningful), real-world problems. These complex problems often do not have a single correct answer, but students can learn from developing solutions for them. The problems are the essential elements and the driving force for inquiry. The students work in collaborative groups to identify what knowledge is needed to solve the problem. This process helps them become self-directed and self-assessed learners and engaged problem-solvers who use critical thinking and reflection to identify the root problem and the conditions needed for a qualified solution (Savery, 2015). The teacher acts as a facilitator of learning through the design of learning activities and has a major role in supporting the development of the metacognitive thinking associated with the problem-solving process.

### 1.2 Learning through creating learning games

A frequently used PBL approach involves the use of games for learning. 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 the creation of games for learning (Kafai & Burke, 2015), enabling the student to have a more active role as a game designer instead of a less active role as a game player. Using a learning-through-game-design approach involves the development of CT skills.

### 1.3 Computational thinking processes

The CT concept has gained attention and has been researched by an increasing number of educators and researchers since the early 1980s (Grover & Pea, 2013). The concept has been defined in various ways (Voogt et al., 2015). Jeanette Wing, for example, defined computational thinking as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (2011, p.1). But it is not an entirely new concept. Papert, for example, argued the need for procedural thinking (1980), and diSessa recommended computational literacy (2000). These scholars had visions about changing how we think and learn and how computers could support more engaging and committed learning processes. Many scholars as well as practitioners break CT into subcategories (Voogt et al., 2015; Wing, 2008), and it has been defined as a broad and comprehensive concept involving thinking and learning processes not very different from PBL processes. But it has also been defined as a narrower concept related to consideration or thinking acts that we need to
learn to be able to program computers to perform procedures. Many of the narrow CT definitions involve four core concepts—decomposition, pattern recognition, abstraction, and algorithms—as well as evaluation of the successfullness of going through these four steps to solve the problem (Voogt et al., 2015; Wing, 2008). These concepts are natural stages for solving a complex problem with the help of a computer and encompass the kind of conceptual understanding needed for a computer programmer to create interactive digital problem-solving of various tasks.

In this experiment, CT is used to reach students’ subject-specific learning goals. But what kind of CT conceptual understanding is needed when the assignment is to learn about curricular subject matter by creating digital learning games?

1.4 Area of investigation
This article investigates: How can students learn specific subject matter by designing and creating digital games? Can the acquisition of CT skills support this learning process? What learning game design processes do students go through when they create digital learning games? And finally, are there elements that connect the various layers of the game design process in a meaningful way that at the same time supports the development of students’ thinking and learning processes?

2. Methodology and research design

2.1 Approach, data collection and analysis
This 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 workshop in Fall 2016, semi-structured interviews with both teachers and students, informal meetings, videos of students’ games being discussed and play-tested, the student-created digital games, evaluation documents written by students, and questionnaires. The analysis was performed by analyzing teachers’ and students’ actions, utterances, and the digital games and by coding the transcribed data using the qualitative research software Dedoose employing an informed grounded theory approach (Thornberg, 2012). The analysis used concept-driven coding (using concepts from the theory and previous empirical data to find themes in the data) as well as data-driven coding (reading the data and searching for new phenomena not known from previous preconceptions of the subject) (Kvale & Brinkman, 2009; Charmaz, 2006).

2.2 Participants and setting
The participants in the experiment were students from a high school class at VUC Storstrøm, an adult learning center in Denmark. The students participated in a full-time education program lasting two years, building games supporting learning the curriculum. Five teachers participated in the game design process.

2.3 Workshops
All the students and four teachers were new to game design. The 20 students in this experiment formed four teams and created four games involving variations over the theme climate change. The students developed their learning-game concepts by following the instructions in an overall learning design in a three-day workshop. The pedagogical approach was PBL, and the only knowledge the students had about climate change in advance came from watching a film about the subject; they had access to relevant texts as well. The aim of the overall learning design was to let the students integrate aspects of relevant academic subjects into small analogue game concepts that were then transformed into digital games. The intention was for the students to become reflective about the academic knowledge; and as a result, they would become academically proficient. CT was not the goal but one of the means to reach the overall learning goals. The students used the digital game design tool Scratch (Scratch, 2017) to create their digital games. The purpose was for students to direct their own learning path 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 by discussing ideas and possible solutions. The students created the learning and game designs in iterative processes. Therefore, the learning goals and process were addressed and questioned in many ways. The learning goals were further addressed in the collaborative peer review/playtests that each student team carried out with other teams.
3. Analysis of thinking and learning processes in creating learning games

The following is an analysis of the thinking and thereby learning processes that took place as the students learned by creating digital learning games. The overall problem or question for the students was: How can we create a learning game teaching about climate change? The learning game construction process involved the students’ considerations about the following four processes: 1) development of learning goals for their specific game for the cross-disciplinary subject matter, 2) learning design, 3) game design, and 4) transformation into a digital game. These four central processes, leading to the creation of the learning games, were deeply connected and interdependent, and the students engaged them iteratively. By separating them in this analysis, it is possible to investigate the characteristic of each knowledge and learning area and process.

3.1 Learning about subject matter and learning goals

The teachers chose climate change as the overall subject and had elaborated the learning goals for the cross-disciplinary subject matter as well as methodological and social learning goals. Since climate change involves and influences social, geographical, chemical, and biological matters, creating a project about climate change demanded that the students developed knowledge about all four involved subject matters. The teachers had crucial roles as guides and discipline experts, they supported the teams, and discussed the content/subject matter of the games with the teams.

The students started the project by studying the learning goals and discussing climate change in the context of the cross-disciplinary subjects. They discussed what they already knew about the subject and where to find more knowledge and brainstormed what educational content the narrative of the learning game could involve in a meaningful way. Two of the overall learning goals were “Analyze and discuss what effect greenhouse gases have on the atmosphere” and “Analyze the global effects of the greenhouse effect using a self-chosen example.” The teachers advised the students to generate ideas based on the leaning goals and to connect them into a narrative in a meaningful way. They suggested that the students chose an everyday learning situation as the narrative for their game and then gradually constructed more ideas for how to involve all the learning goals. This demanded that the students thought about how to move between the choice of relevant and meaningful content and the design of relevant learning situations in the game, which would enable the future learner/player of the game to reach the game’s intended learning goals.

The students had educating conversations about what to teach within the game, becoming self-directed learners in this process, but the teachers also had vital roles. Two of the teachers, for example, supervised each team, asking them to explain how the various learning goals were met in their game. If the students found it difficult to address a learning goal, the teachers pointed them to a relevant article about the subject matter. Then the teachers discussed the learning goal with the team and co-ideated on how they could implement this goal in the game.

Figure 2: Examples of choices offered after educating episodes in two games

Some of the affordances learning games have, as media, are possibilities for designing interactions, giving choices and connections, and showing cause and effects as well as consequences in the game. The analysis suggests that this affected the students’ choice of content as well as narrative for the games. Several of the teams chose to design games that in various ways let the learner/player choose between options in the game, similar to the cause-and-effect systems grounded in the subject matter. For example, by offering complex choices between the cheapest product or service or the greenest solution (Figure 2)—such as when the
offered sun-energy solution that seemed to be the most climate-friendly possibility actually turned out to be the opposite when taking the production process of the solar cells into account. The students had to think about how to design these various systems of choices, causal connections, and opportunities for interactions, and, according to the teachers, this led the students to develop new knowledge about the same relevant systems within their subject matter.

3.2 Learning design process for the learning games

The students were asked to create a game that both taught and evaluated the future learner/player of the game about climate change. Problem identification for the learning design phase involved questions like *How can we create a learning design within a learning game?* This involved understanding principles of what a learning game is and what learning processes are. The creation of a learning design traditionally involves considerations about who the participants are, what learning environment the learning takes place in, what the learning goals are, what content should be introduced for the students to achieve these learning goals, and what learning activities and evaluation processes the students should experience for them to go through the intended learning processes and reach the learning goals. From previous research, we learned that the abstract learning design elements are not obvious to high school students. Therefore, the students were introduced to a simple learning game example in Scratch (2017) that taught the students about learning design elements in a learning game (Weitze, 2017). The students could use this example as a *vision and thinking tool*, which made it easier for them to imagine how they could create their own learning design for a learning game.

3.3 Creation of common learning design “systems” when creating learning games

As the students started conceptualizing their learning games with paper and cardboard, the analysis showed that the students deconstructed the learning design for the games into the following learning design areas: a) learning environments, b) communities of practice, c) learning activities, and d) learning paths for their learning game concepts. The construction process was categorized by the students into the four areas in the following ways:

**a) Learning environments—situated learning experiences:** When designing a learning game the students needed to think about how to create learning situations within the games. These learning situations or scenes in the game could involve relevant learning elements, such as backgrounds illustrating climate change or its consequences or objects, for example, giving the player the choice between solar panels or wind mills as energy sources in the game. These learning environments contributed to the players’/learners’ learning processes as they played the game.

**b) Communities of practice:** In traditional learning situations, the learning community of practice involves peer-relations as well as student–teacher conversations and interactions. The same occurred in the learning games. The teams formed small communities of learning within the game concepts. Some games also invited the player—outside the game—to listen and learn. The in-game-characters in these game-communities had various roles, including teacher, helper, apprentice, the good (climate) guy, and the bad (climate) guy. These characters enabled educating conversations to take place during the game-play.

**c) Learning activities:** Depending on pedagogical approach (for example, instructional or social learning approaches), learning interactions between agents participating in a learning situation generally take place as instruction, demonstration, imitation, dialogue, discussion, or co-construction. Examples of previous learning activities in students’ learning games include inviting the learner/player 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, and learning and assessing by doing in the game (Weitze, 2017). One of the main strategies in the design of learning activities, used in this experiment, was to create educating dialogues between two in-game-characters or letting several game-characters first teach and then invite the learner/player to act by choosing between various opportunities in the game (stealth assessment) and thus learn from the consequences of these choices. That is, if the learner/player had been listening and thereby learning, she would know what to choose.

**d) Learning paths—narratives and interactions:** The challenge for the students was to then combine and weave the above three learning design areas into meaningful narratives in the climate change
learning games. The students did this by creating learning paths (Figure 3)—inventing a narrative with game-characters that took part in relevant learning activities in various procedures over time. This demanded procedural thinking of the students as well as the building of hypotheses, arguments, connections, and causal explanations about the subject matter within and around the digital learning games.

The analysis showed that the students learned and approached their learning goals through collaborative discussions and work processes and reflected on the problem of creating a learning design while ideating and constructing their game concepts in iterative processes.

3.4 The students’ game design reflections

Though the game design and learning design were deeply intertwined, the following is an attempt to analyze relevant game design elements in the students’ constructed learning games. When setting learning “into play,” traditional game elements are action space and narrative, choice, challenge, rules, feedback, and game goals (Weitze, 2016b). Some of these elements were directly connected to the common learning design elements that the students used. Turning learning design elements into game design elements can be regarded as the students’ further development of their vision for a learning game with specific learning goals into a more specified and conceptualized learning game design. In their creative and innovative work, the student game designers kept moving between the abstract learning goals and the specifications for a concrete learning game design as well as between the whole and the details of the learning game concept though their continuous reflections (Löwgren & Stolterman, 2007).

Action space, narrative, and game goals: An example of connections between learning design and game design elements was that the game design element action space in the students’ games corresponded to the learning environment. Also, the game design element narrative corresponded with the learning path the students used to connect the relevant learning goals and content in their learning games. The narrative also presented the game goal by creating a story with a direction that was meaningful and connected to the learning goals in a relevant way. One team explained: “Our climate-polar-bear game involves various scenes with horrible pictures of what climate changes will do to the earth if we continue living like we do at the moment. Our idea is to make a game where you can save the planet by pursuing various climate-connected challenges to save the world, and if you fail, the earth ends up being destroyed.” This game involved a learning environment and narrative that were connected to the learning goals, and the game goal was evident: the player/learner had to save the world.

Choices, challenges, rules, and feedback: The content (subject matter) was presented through the narrative (in monologues and dialogues) and in the learning activities in the students’ games. The learning activities were formed as choices, challenges, rules, and feedback—opportunities for educating interactions in the game. The choices in several of the teams’ learning games were created so the player/learner had to create a hypothesis about how to answer from the knowledge that was provided earlier in the game. One team discussed the interactions in their game: “In our CO2 game the player, for example, is challenged on his knowledge and has to choose between two green energy sources. He has to listen carefully to our game-characters, since it is not the obvious choice he should take. So, in this way the rules of the game are decided by authentic facts. If the player tries to save the environment, he will collect money for building a fantastic sustainable farm, and the level of CO2 will go down. We have discussed if we should create a game-rule, being: if the player gives the wrong answers three times, then he should be told: ‘You are terrible to the environment,
and you know nothing,’ and then it is the end of the world!” These students had used rules that were based in facts from the subject matter (you will not survive if you make unsustainable choices), and the consequences were inspired by real-world consequences. The player/learner received feedback instantly about whether he had understood the learning intentions (Figure 4). All games used traditional game design elements as a way to set the learning into play.

![Figure 4: Example of feedback in the game](image)

The students chose to create interactions in the form of meaningful choices with meaningful consequences in their games. For example, in the CO2 game about sustainable farming, the player had several offers to choose between various opportunities. With the information she had been given in advance in the game, she should be able to choose the most sustainable energy source. This gave the player/learner agency to make her own choice and gave her experience with the subject matter presented in the game.

3.5 Computational thinking in action—transformation into digital learning games

The students were inexperienced in using the digital game design tool (Scratch), and some students hesitated when approaching the technology. Previous research showed it is important to guide the students by introducing them to small tutorials for the tool (Weitze, 2017). This part of the process required the students to transform the specifications for the learning game concept into a functioning digital game. The students used their story boards (Figure 3) illustrating the learning environments, communities of practice, learning activities, and learning paths as a basis for discussions about how to create their digital games. In this process, the students were presented with many dilemmas. Sometimes part of their concepts proved difficult, or perhaps even impossible, to transform into digital procedures—they had to learn to think computationally.

The ideas and solutions did not always work out as planned. Sometimes this was because the affordances of the game design tool were too limited, or the students did not know the tool well enough to find an appropriate solution. But sometimes the “conversations” with the game design technology (Schön, 1992) sparked other solutions that better met the students’ intentions with the learning games. In these boundary areas, the learning game was transformed from a vision with specific learning goals into a concept for a specified learning game design and then the transformation into a functioning digital game—an operative image (Löwgren & Stolterman, 2007). These boundary areas often represented dilemmas and processes where a “creative leap” took place. Here the learning game designers exceeded the limits of the present, and by handling these dilemmas the students were forced to learn, be innovative, and create new concepts.

3.6 Computational learning elements in the students’ games

The analysis of the current experiment showed that the abstract learning design elements the students designed for in their games to some extent were significant and could be decomposed into specific patterns that could be performed by procedures or algorithms. This should of course be seen in light of the learning games being quite simple games, given that the students were novices in game design and the short amount of time they were given to develop their games. These computational learning elements have, however, proved efficient as inspiring examples for students in their digital learning game design in later experiments.

The following are examples of the computational learning elements in the students’ games. Again, these were connected to the previously mentioned abstract learning design areas. The students created:
Learning environment and learning objects: This demanded that the students imported backgrounds and objects into the digital game.

Communities of practice: This demanded that the students imported or created various relevant characters, teachers, and learners in their games as well as showed and hid these characters.

Learning activities: There were many examples of computational learning elements for learning activities and interactions, illustrating the benefits of using games to teach as opposed to e.g. books. Activity examples were:

1) Dialogues in the game, conversations with one or more characters: This demanded that the students broadcasted messages between the characters, enabling one character to react to what another character sends, creating dialogues, other actions, and interactions in this process.

2) Methods for advancing in the game and receiving feedback on whether the learners/player choices were correct: This demanded that the students created various levels and scenes in the game. This was done e.g. by broadcasting messages to change backgrounds and objects.

3) A way to explore the environment: This was e.g. done by programing the arrow keys.

4) Evaluation in the game: This could be programmed in various ways. For example, by using the CT concept, events describing one thing cause another thing to happen (Brennan & Resnick, 2012)—e.g., letting two choices lead to different consequences, giving different feedback depending on what the correct answer was.

Creating learning paths in the game: This took place when the students mentally decomposed all the various activities into small entities and then turned them into procedures in the game—for example, by combining an informative dialogue with a possibility to explore the learning environment followed by an opportunity to be evaluated in the game. The students looked for patterns when they repeated various identical procedures or algorithms in the game, altering the dialogues or background when they wanted to create serial learning situations.

That students were sometimes frustrated if they did not have time to finish their digital games proved the importance of teachers continuously conducting meta-conversations with the students discussing and confirming how and what they learned while creating their games. That said, we saw proud students showing their games to fellow students at the final exhibition.

4. Discussion and conclusion
This article investigated how students could learn specific subject matter by designing and creating digital games and whether the acquisition of CT skills could support this learning process. It also explored what learning game design processes students carried out when creating digital learning games and what elements were found to connect the various layers of the game design process in a meaningful way, supporting the development of students’ thinking and learning processes.

The analysis found that the learning game construction process involved the students’ considerations about four central areas and processes within these areas that were deeply connected and interdependent: 1) game-specific learning goals for cross-disciplinary subject matter, 2) learning design, 3) game design, and 4) transformation into a digital game (Figure 5).

As the students started conceptualizing their learning games in analogue materials, they typically deconstructed the learning design for the games into the following learning design areas: learning environments, communities of practice, learning content, learning activities, and learning paths for their learning game concepts.

When they moved on to set the learning design “into play,” the applied game design element in many ways corresponded with the learning design elements. For example, the game design element narrative corresponded with the learning design element learning path that was used to connect the relevant learning goals, content, learning activities and evaluation processes in their learning games.

Finally, when the students transformed the abstract learning design elements into a digital game, they needed CT skills. CT was used to decompose the tasks, simplify the process by looking for similar patterns, and create algorithmic procedures performed in the game design tool. In this part of the process the students created learning paths in the computational systems, which allowed the learner/player to experience in-game conversations and explore, get feedback, and be evaluated in the games.
The analysis suggests that the use of learning game design as a learning approach—with possibilities to design interactions, choices, connections, consequences, and cause and effects in the game—affected the students’ choice of content as well as narrative for the games and thereby what and how they learned.

**Learning goals for the cross-disciplinary subject matter—thinking and designing**

| Choice of game-specific learning goals and content | Ideas/brainstorm/initial learning story | Mindmap/storyboard/interactions |

**Learning design phase—creating learning design elements**

| Learning environments and learning objects | Communities of practice | Learning content | Learning activities - What you can DO in the game | Learning paths for learning game concepts |

**Game design phase—connecting learning design and game design**

| Scenes in the game | Actors in the game | Content, rules, and subject-matter systems | Choices and learning activities | Challenges and learning activities | Feedback and evaluation | Learning path and narrative | Game goals and narrative |

**Transformation into a digital game - using computational thinking**

| Deconstruct abstract learning and game design | Distinguish patterns in learning design and game design elements | Design algorithmically performed procedures |

**Creating computational learning activity elements inside the game**

| Exploring the environment | Creating conversations | Creating actions in the game | Advancing and receiving feedback | Evaluating (stealth assessment and test) | Creating learning paths in the game |

*Figure 5*: Central conceptual areas and elements the students reflected on and created in the learning game construction process

The materials in this experiment were used as “discussion partners” by the students. They learned by thinking, doing, thinking and doing again, working through the various layers of processes in an iterative process (Figure 6). As the students designed narratives, built hypotheses, created arguments and choices with different consequences, and demonstrated connections and causal explanations about the subject matter in the game, deep thought processes were demanded of the students. According to the analysis of the interviews with the teachers and observations from the experiment, this appeared to give the students opportunities to learn about 1) the cross-disciplinary subject matter, 2) learning to learn, and 3) CT. According to the teachers, working with designing learning games led the students to develop new knowledge about relevant rules and cause-and-effect systems within their respective subject matter areas.

*Figure 6*: The creative processes in the boundary areas between vision and concept and concrete object

To summarize, the students experienced how to work from a PBL approach as they started to create ideas and visions for the specific subject matter they wanted to teach for their future players to reach specific learning goals. They then turned these visions into learning game concepts involving learning design and game design elements. Finally, they then transformed the learning game concept into a functioning digital game—a concrete digital object. Despite being areas of dilemma, frustration, and hard work, the boundary areas
between vision, concept, and concrete object sparked the students’ creativity and innovative solutions, and the students’ thinking and learning processes that were demanded empowered them to create ideas and solve problems when learning through the design of digital learning games.

5. References


