Design Thinking, Game Design, and School Subjects: What is the Connection?

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Abstract

If you want to learn how to become more creative, better at collaboration, or want to develop your critical thinking skills playing games can be a powerful activity. If you want to be even surer, then build a game. This was the conclusion of a review performed by Qian and Clark (2016) on how Game-Based Learning can develop 21st Century Skills. Understanding relations between the broad categories of “learning”, “design”, and “games” is crucial in the research project Game-Based Learning in the 21st Century (GBL21.aau.dk), where we introduce game design activities through 24 teaching units for three subjects respectively Math, Science, and Danish. However, finding meaningful relations between design processes, game tools, and school subjects have proven to be a challenging task. In order to handle this challenge, our paper describes existing research on how to design games as a learning activity. The contribution of the paper is to provide a better understanding of the relations between the three domains of design thinking (DT), game tools/activities, and curriculum in order to develop, game design activities, which are relevant to teaching subjects. The contribution is an insight into research in game design as an approach to teaching; as well as, a review of relevant theories on designing as learning activity, and a discussion of how to implement these approaches in teaching.

Keywords: Game design, design thinking, school subjects, learning goals, learning outcome

1. Introduction

Forget about novels and movies, the 21st Century is the era of games according to game designer and scholar Eric Zimmerman (2013). Whereas the 20th Century belonged to information, the 21st Century puts information at play. We live in a world of systems and games are metaphors of such systems. There is a huge need for creativity and innovation, which a playful approach nurtures (Zimmerman, 2013). Even more, we should not engage in games as consumers only, we should think as designers according to Zimmerman (2013). Further, designing games is an effective way to learn, this was explored as early as mid-20th Century by Piaget (1951), who studied game-play as a:

[...] venue for children to develop and exercise their understanding of rules and considered games of construction to be the highest form of game play, as games require children to build representations of the world according to their understanding (Kafai 1995, 1998).

James Paul Gee (2003) agree with Piaget, that games have a great learning potential and argued that schools should indeed learn from the pedagogy of games. According to Gee (2003) games are great learning environments and he identified 36 good educational principles could be found in design and play of games.

Kafai and Burke (2015) build on Piaget’s understanding of games as complex systems, that allow players to learn about rules, world, and interaction, as wells as his constructivism, in which children play to learn and develop. However, Kafai and Burke (2015) also mention games as social and cultural dimensions of constructionist learning, which include building games not merely playing them. This constructionist approach echoes Seymour Papert’s (1995) ambition:
If one does belong to a culture in which video games are important, transforming oneself from a consumer to a producer of games may well be an even more powerful way for some children to find importance in what they are doing. (Papert, 1995, p. iii)

Piaget, Gee, Papert, Kafai and Burke all argue that games are good for learning as they describe games as complex structures, as cultural and aesthetic products, and as learning environments. We want to explore the potential of designing games for learning Math, science and Danish (L1) as well as for improving ideation, modeling, collaboration and process management across subjects.

In this paper, we discuss how design and more specifically design of games may scaffold learning processes, which allows students to inquire about the subject matter. We argue that games are systems as well as metaphors of more complex systems that allow players to toy with complexity as they analyze and synthesize game elements.

2. Research Context
The basis of this paper arose through the work of developing 24 game-based teaching units in the project Game-Based Learning in the 21st century (GBL21). GBL21 aims to develop students’ design competencies through game-related DT activities within Danish, science and mathematics. This is done through an intervention involving 19 schools across Denmark carried out from mid-2019 to end 2020. During these 1.5 years 5th and 7th grade students will engage in, designing in and around digital and analogue games in relation to the three subjects. The project aims to compare these students to students from 25 schools acting as control group in relation to their academic and social self-efficacy, social and emotional well-being, their perception of key curricular activities, as well as, the students’ design competencies. The assumption is that our designed interventions will nurture the students’ design competencies, specifically their abilities to emphasize with user needs, their ability to collaborate, to plan and prioritize design tasks, to generate new ideas, and to model design solutions using various types of representations. This place a high demands on our teaching units. Learning from previous research on designing games as a pedagogical approach has been crucial. Further, looking into the design process as a learning activity has been fruitful, and finally mapping these findings and implementing them into a Danish school context is needed.

Accordingly, this article first provides an insight into research in game design as an approach to teaching; then we review relevant theories on designing as learning activity and finally we discuss the literature in relation to implementing these approaches in teaching.

2.1 Case: Teaching Units
The teaching units for the GBL21 project have been developed based on three different approaches to design activities. The three approaches involve 1) design through games, where students redesign existing games in order to address design challenges, 2) designing with(in) game (tools), where students come up with or modify design solutions using digital game tools and game worlds, and 3) designing around games, where students design and produce different types of texts that relate to games. The three different approaches are shown in figure 1.
As an example, this paper will focus on a particular teaching unit involving redesign of games, where students solve complex challenges by modding and redesigning existing board games. The teaching unit has been developed for Danish as a subject (grades 5-7) and is entitled *Design a game about online communication*. The design challenge for this teaching unit is to explore online use of toxic language and then redesign existing board games such as *Ego*, *Partners*, or *Ludo* in order to help other students understand and manage toxic language. In this way, students have to employ a broad sense of different design competencies, which involve:

1) Researching examples of toxic language on social media sites.
2) Interpreting their data and identifying patterns.
3) Use these insights with their existing knowledge of and experience with board games in order to generate ideas for a redesigned board game that may be used to address the challenge with toxic language.
4) Developing a prototype for their redesigned game.
5) Testing their prototype with other students in order to see how their redesigned game address the design challenge.

We will be using the example to discuss challenges and possibilities in making links between students’ design processes, understanding of game design, and school subjects.

### 3. Linking Game Design Activities with Curricular Aims

Game design activities may be highly engaging and beneficial in terms of developing students’ 21st Century Skills (Qian & Clark, 2016). However, given the broad scope and purposes of game design activities, it is often difficult to link game design processes to specific curricular aims. We have identified three different approaches to addressing this challenge across different learning contexts.

One approach is create a game design curriculum, where game design is a core learning activity. This approach is commonly offered through various types of electives, summer camps or after-school programs, which exists outside the rigid structures of formal schooling. In Denmark, the most well-known example is the Coding Pirates movement, which is a large non-profit, voluntary organization that aims to develop children’s understanding of and ability to create with digital technology. This often involve game design activities using Scratch and other game design tools. These game design processes are supported by voluntaries who are often not teachers nor pedagogues. Furthermore, the aim of Coding Pirates is not educational per se. Another example is the recently launched Make Room! project, which is a US-based network of youth game making studios. These out-of-school
initiatives can be seen as affinity spaces (Gee, 2003) or as examples of connected learning (Ito et al., 2013), which build on the shared interest and passions of facilitators and young people in relation to game making.

Another approach is to create a quest-based curriculum, which aims to develop school curricula around student-centered quests inspired by the aims, practices and knowledge forms of playing and designing games. A well-known example is the “Quest 2 Learn” school in New York City. Here, the school subjects are interdisciplinary and draw on insights from systems thinking as well as DT practices making it easy to form curricular links when designing and redesigning of games - e.g. by using the GameStar Mechanic software to “fix” broken games in relation to curricular aims (Salen et al., 2011). Other examples include Danish boarding schools such as Epos and Østerskov Efterskole, where the pedagogical practices involve narrative role-playing activities as well as design activities.

The third approach tries to integrate game design activities within the existing framework of the subject-centered curriculum, which characterizes most public schools all over the world. This is perhaps the most obvious, but also the most difficult approach to working with DT and game design activities in a learning context. There are several reasons, why it is difficult to integrate game design activities within the subject-centered curriculum. First, working with DT and game design does not necessarily resonate well with the existing aims of the school curriculum. Secondly, game design activities may easily clash with teachers’ subject-specific teaching practices and everyday teacher habits. Thirdly, working with game design requires sufficient resources in terms of time, space, learning resources and game design materials in order to become meaningful. However, it may often be difficult in schools to locate and utilize these resources. In the GBL21 project, we have chosen this third approach in order to be able to scale the approach for the potential benefit of all Danish schools. In this way, our example with the teaching unit Design a game about online communication is intended to be used by Danish teachers and is designed to support learning goals within this subject. The teaching unit relates to a range of academic objects within Danish, such as learning about the mechanics of online communication, but also making an interview, providing feedback, writing an instruction, and working with target groups. Performing these activities is legitimized by designing a game system for others.

Before we go more into detail with discussing the choices guiding the game design activities developed for the GBL21 project, we will take a closer look at the theoretical assumptions about how students learn through game design processes.

4. Learning through Designing

Papert (1980) established constructionism highlighting how the construction of artifacts can indeed be a fruitful approach to learning. Constructionism is an extension of constructivism, as learners build not mere mental constructs but actual artifacts as part of the learning process (Papert, 1980). The design itself becomes an object-to-think-with: something external, sharable, and meaningful to the learner (Papert, 1990). This view emphasizes design materiality as externalized signs of reasoning rather than as assessing it as a product.

Yasmin Kafai also considers the design process as a way to externalize thinking and problematize focusing on the product when introducing design to learnings contexts. In her 1995 book, Minds in Play - Computer Game Design as a Context for Children’s Learning, Kafai explored design of computer games as a context for learning tapping into children’s play culture. Sixteen fourth graders were spending one hour per day for six months making games through programming in order to teach fraction to younger students, they reflected upon the process in notebooks, presented and discussed their process along the way (Kafai, 2012). Building a theoretical approach to her project Kafai considers ‘learning through design’. She problematize how design and learning might have different goals:
The design theorist is interested in the final product as such; for the learning theorist, the product is a spin-off of the process that led to it. With these different interests, theories of design and theories of learning have little to say to each other. (Kafai, 2012, 7).

However, the process should be the focus in a learning environment (Kafai, 2012). Framing learners and designers as “constructing meaning”, we can close the gap between design and learning (Kafai, 2012). Allowing students to be designers: “[...] puts students in charge and engages them in a continuous dialogue with their own ideas and with the ideas of intended users and co-designers.” (Kafai 2012, p. 15). Furthermore, designing a game is designing for others, and thus, it includes critical thinking and judgement. Students have to ask themselves: Will this be meaningful to the players?

Another, take on ‘learning through design’ is to consider John Dewey’s suggestions for learning. Dewey (1938) argued that we learn in interaction with the world, handling real problems. Köhler and Mishra (2005) elaborate:

The act of design is essentially a dialogue between ideas and the world, theories and their application, concepts and their realization, tools and goals (Dewey, 1934; Mishra, Zhao, & Tan, 1999). This dialogue lies at the heart of true inquiry, involving as it does the construction of meaning and the evolution of understanding through a dialogic, transactional process (Bruce, 1997; Dewey & Bentley, 1949; Rosenblatt, 1978)

Dewey (1938) indeed links inquiry to transformation when he defines inquiry as:

...the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified ‘whole. (Dewey, 1938, p. 104)

When designing students do perform a controlled and directed transformation of a problem that is indeterminate, manipulation with the elements of that situation with the goal of create a new design - a unified whole. They engage in a process of inquiry. Design is inquiry.

In the teaching unit Design a game about online communication students inquire about their online communication habits, and on how they can invite others into a dialogue through a game setting through the design process. In this dialogue, the game board, - challenges, and - pieces are pivotal, as they make students externalize how they think about online communication, which allow them to discuss and reflect upon the topic together. The board game represents rules, the realm of the online communication, and creates an interaction between players and with the topic. Creating such a game requires students to understand, what toxic language is, how it appears and how to respond to it. The project is not evaluated by assessing the board games they develop, but on how it makes sense in relation to the topic. The design process is thus considered as a meaning making process; a dialogue between the students’ ideas about good communication and the actual communication online happens.

4.1 Challenges by Bringing Design to Schools

We have identified three problems that need attention when engaging students in design activities to learn:

1. Problem: Design activity does not align with academic goals
2. Problem: Students do not experience learning something professionally or do not associate learning with the subject matter
3. Problem: The overall complexity that arises from engaging in an exploratory process
In this section, we will focus on how to frame the activity rendering it relevant to academic content and highlight issues identified.

When engaging in design processes the starting point is a good design challenge in order for the activity to be meaningful. The design challenge presents constraints and directs students’ thinking:

[…] problem constraints actually encourage the creative leap by directing student attention to certain kinds of thinking procedures—not to solutions—and by deliberately eliminating conventional or predictable options. (Davis 2011, 154)

Davis (2011) suggests that a design challenge could be designing a vehicle that uses the locomotion of an insect as an analogy for moving. Thus, the constraint (the analogy) helps direct the activity. Davis (2011, p. 170) has summarized criteria for good design challenges (see Table 1). However, adhering to these criteria can be challenging. Davis (2011) suggests how to handle each of these (see Table 1).

<table>
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<tr>
<th>Criterion for good design challenges (Davis, 2011, p. 170). Good challenges are:</th>
<th>When implementation in teaching acknowledge that:</th>
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<tr>
<td>Open-ended: The solution to the problem is not known at the start of the assignment.</td>
<td>Learning outcome should be regarded as activities and experiences, and the thinking behind these can be tested (Davis, 2011)</td>
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<td>Situated: The form of the solution arises from the conditions or circumstances surrounding its use. This form includes its physical, cognitive, cultural, technological, and economic dimensions.</td>
<td>Design challenges should that allow students to explore and define the problem space. The design challenge should encourage students to consider not only parts of the solution, but how these parts relate to each other as a system, and how this system relates to other systems.</td>
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<td>Responsive: The problem statement and outcome are accountable to more than the designer’s own interests.</td>
<td>Through the design challenge, students should be encouraged to empathize with others.</td>
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<td>Values-laden: The solution to the problem requires a ranking of competing priorities.</td>
<td>Design challenges should include a complexity that encourage students to resolve competing values.</td>
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<td>Integrative and holistic: Solving the problem relies on information and skills from more than one discipline and proceeds from inception to evaluation of outcomes.</td>
<td>Design challenges transcend the boundaries of subject and thus demand making links subjects.</td>
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<tr>
<td>Authentic in assessment strategies: The methods for generating and evaluating ideas are congruent with the constraints and affordances of the problem.</td>
<td>Design challenges frame what products can be made as well as the thinking employed.</td>
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In summary, design challenges frame a certain thinking, students should be encouraged to consider not only parts of the design and their internal fit, but also consider the problem in its wider context. Through the process students should empathize with others and consider the values that are reflected in the design product. The design challenge is cross disciplinary at its core, and thus restricting it to one subject might be tricky. Finally,
when assessing the students work with the design challenge, it is crucial to give them feedback at their thinking - why and how they chose to do what they have done.

With the teaching unit *Design a game about online communication* the challenge is to design a board game that helps others reacting positive online communication experiences. This should help them consider the issues about online communication, as well as, how the game itself can be made so that it is meaningful in this context. To do that the students need to know a lot about online communication and empathizing with the potential players. They need to consider why the tone online is sometimes very harsh and how this can be prevented, and again how to translate this in to game choices and consequences. Finally, the teacher scaffolds an assessment process in which students reflect upon their learning in relation to process and product.

Looking at Davis (2011) attempt to establish operational understanding on the concepts linked to working with design processes in school it is evident, that this pedagogy places demands on the teacher. Retna (2016) is interested in these challenges and notes that some of the challenges are:

...inadequate resources, time constraints, fear of poor grades and the difficulty of shifting to a new way of teaching and learning that differs vastly from the traditional approach. (Retna, 2016, p. 5)

Further, Retna (2016) warns against taking a ‘piecemeal’ approach to redesigning the curriculum. Teachers and students were interviewed and they appreciated how utilizing DT allowed students to become more empathetic towards others and that it spurred a different way of thinking (Retna, 2016). However, there were also concerns. First of all teachers statements indicated that they thought DT would apply best to students with high academic excellence. Retna (2016) points out that there is an ambivalence between teachers praising DT as being an effective learning approach on one side, and then on the other suggesting that it is not suited for their own students. Retna (2016) concludes:

This ambivalence may be a reflection of the realities faced by practising teachers (with limited time and resources), in utilizing a system which places greater demands on students, and hence on them as teachers, than more conventional methods. (Retna, 2016, 11)

Both students and teachers consider DT more time consuming and thus less efficient than more conventional methods (Retna, 2016). When stating so, the students and teachers are considering how well DT helps students in meeting the goals of a given subject matter. Furthermore, teachers are concerned with the fit between their subject and DT. This is evident in this statement by one of the participating Math teachers: “I teach Maths. It is very difficult to use DT. In Maths – A plus A is just 2A. There is nothing about design thinking that changes that.” (Retna, 2016, p. 11).

The study was conducted in Singapore where there is much focus on exams (Retna, 2011). However, considering learning goals is a widespread demand placed on teachers, and thus the issue how relevance to GBL21 which is set in Denmark, where learning goals have been set through a common curriculum for the national school. Retna (2016) suggests reconsidering both curriculum and the exam form to accommodate DT. This is not possible in GBL21. We have chosen to integrate DT through teaching units into the subjects as they are, and learn from the potentials that occur and issues arising from that situation.

Caroll et al (2010) quote a teacher who underlines, that a heavy focus on fact-learning should not be a teachers ambition, and that DT helps: ‘We’re not just going to think about a problem, but we’re going to think about how to think about a problem’. However, Caroll et al (2010) also experience that students had difficulties in relating the DT project with the subject (Geography), thus one of their recommendations is to have clear learning goals that are communicated to students, which we have strived to do with the GBL21 teaching units.
5. Building Games to Learn
Qian and Clark (2016) reviewed 137 papers about game-based learning. Twenty-nine of these papers reported the influence of using games in teaching on the development of 21st century skills especially on critical thinking. Of those studies that reported a large effect the design-based approach came out as a winner with 13 results with high impact.

The most renowned and best-documented experiment with building games as a pedagogical form is “Quest 2 Learn”. It was the first of its kind when it opened in 2009: A public school that encouraged students to “taking on identities as designers”, with a curriculum designed around the core principles of game design and play (Salen, 2017). Teaching a standardized curriculum with an emphasis on empowering: “students to see the world as made up of interconnected systems” (Salen, 2017).

According to Salen (2017, p. 63) design of games have a unique transformative potential:

Design can be defined as the practice of exploring the tension between the existing and the potential. It is a mode of transformative action that, according to design historian Clive Dilnot, allows us to see “how we negotiate the limits of what we understand, at any moment, as the actual.” Game design pushes this concept even further by legislating through the design of possibility spaces that arise from a set of rules. These rules give shape to the limits of the actual, and provide opportunities for players to discover these limits by pushing against them in creative ways. When this happens, the experience of play is born, in all of its transformative potential. (Salen, 2017, p. 63)

Integrating this approach into everyday teaching required a change of culture, where teachers were willing to take risk with their curriculum and to be more experimentive (Salen, 2017). This was supported through a collaborative approach in the Mission Lab, where teachers and game designers worked together to push the boundaries of teaching (Salen, 2017). When the Math teacher told Retna (2016) that A plus A is 2A, and that DT cannot change this, the teacher might be missing a point: That the purpose of designing - and especially integrate game-like thinking - is to offer students challenges as a starting point, that designing games provide a context that might render e.g. Math meaningful (Salen et al, 2011).

6. Building Game Design Teaching Units
When considering the experiences within the field presented above, we considered the following crucial when developing game design teaching units to be integrated into subjects:

a) Use design- and game challenge as a context for and reason for engaging in academic content
b) Consider design and play to be meta-cognitive activities that allow students to experiment, observe, judge, and critically assess their endeavor.

6.1 Design- and game challenge as starting point
Designing games students focus on challenges and complexity but in a controlled micro-world (the game). To start each teaching unit with a compelling challenge creates a context for the academic content that might make it meaningful for students. The design challenge should be made so that students use their understanding of the academic content to solve a problem (Cook & Bush, 2018; Kelley et al, 2015). Thus, the game design challenge works as a structure that frames the learning situation.

This challenge should:

- Allow for more solutions (open-ended)
- Relate to the everyday of the students (situated)
- Make them consider others point of view (responsive)
• Require prioritizing of perspectives (values-ladden)
• Integrate both language and methods from the academic content as well as game-like thinking (integrative and holistic)
• Allow for an assessment that makes sense as a continuation of the project and relate to the students thinking behind their design choices (assessment)

The challenge of the teaching unit *Design a game about online communication* was to make a board game that invited players to engage in a topic well known to them. They were asked to take the view of potential players, considering their values in relation to the topic and that of potential players, allowing them to use their knowledge from Danish, and was assessed as an externalization of their thinking about the topic, as well as, their creativity and collaboration.

6.2 Designing and play as meta-cognitive activities

Game designing is a metacognitive activity as it covers both relating to the challenge in the game, but also how to make an abstraction of a design challenge and a recipient (the player of the game).

For instance, if we consider the challenge of making a game that highlights a hard tone online - making it into a board game you need to understand the how conversation forms online, who is trolling and how can it prevented, and then simplify these to make it into challenges, choices and feedback in a game. The students get immediate feedback from the situation, working with this complexity both when designing and play testing the game. Thus, students think through their ‘hands’, when they engage with materials and models, expressing their understanding through prototypes. Games are indeed not just systems but also materials and aesthetics that lends themselves to dialogue, speculation, and inquiry.

Engaging in game design projects we suspect will challenge students’ ability to reflect upon their own thinking. To think about how they think about problems.

7. Conclusion

In this paper, we have discussed the potentials and pitfalls when bringing game design to students. We have done this as a preparation for creating teaching units in the research project GBL21 that brings game-like design teaching to 19 Danish Schools. We have chosen to integrate these units into the curricula of science, Math, and Danish knowing that this is a challenge. Through this paper, we have shown that game-like design frames the learning situation through design challenges that take their point of departure in the academic content, but also provides a context for this. We have also shown that game-like design activities are metacognitive as they involve systems thinking as well as thinking through the material design situation. Finally, games-like teaching invite learners into a dialogical space where they negotiate understanding of a situation need to form hypothesis on what could be and should be (design ideas) and can indeed test them in real life. Through game-design, students play with limits of the actual, explore possibility spaces, and toy with complexity as they analyze and synthesize game elements in relation to a given topic. Furthermore, the games relate to more than school as they are metaphors of something else (e.g. online communication culture). The games also tap into play culture and thus affords playfulness and experimentation that lends itself to inquiry and transformative learning.

Because of these insights in our future research, we will focus on design processes as dialogical learning processes in which the teacher and students use language and materials to negotiate and externalize their thinking. We will scaffold the creation of good design challenges that invite students into the process while allowing students to learn and use academic content, in order to integrate game design and subject oriented teaching even more.

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