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Using Game Design to Teach Informatics and Society Topics in Secondary Schools

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Abstract: This article discusses the use of game design as a method for interdisciplinary project-based teaching in secondary school education to convey informatics and society topics, which encompass the larger social context of computing. There is a lot of knowledge about learning games but little background on using game design as a method for project-based teaching of social issues in informatics. We present the results of an analysis of student-created games and an evaluation of a student-authored database on learning contents found in commercial off-the-shelf games. We further contextualise these findings using a group discussion with teachers. The results underline the effectiveness of project-based teaching to raise awareness for informatics and society topics. We further outline informatics and society topics that are particularly interesting to students, genre preferences, and potentially engaging game mechanics stemming from our analyses.

Keywords: game-based learning; game design; project-based teaching; informatics and society; cybersecurity

1. Introduction

This article discusses the use of game design as a method for interdisciplinary project-based teaching in secondary school education. Secondary school education has to integrate a lot of learning content that is defined in the curricula, resulting in considerable pressure to accommodate this. Thus, incorporating specialised and interdisciplinary subjects into regular teaching is a challenge. Our contribution outlines a specific case of interdisciplinary project-based teaching. Over a period of one year, secondary school students created analogue and digital games in computer science and arts classes. The games incorporate topics from informatics and society, which encompass the larger social context of computing, such as copyright, privacy, cyberbullying, technical literacy and social media use. The learning effects observed in a quantitative survey are presented with full detail in a different paper [1]. In terms of learning goals, the primary objective of the project was not only to convey knowledge around informatics and society topics to school students but to let them experience academic research practice, in this case game design and analysis, firsthand. The core contributions of this paper are based on qualitative analyses of materials created by students and a group discussion with teachers. The goal is to outline how such a project-based learning approach can be embedded in schools, which topics are interesting to students and are reflected in the work they submit, and which game elements and genres they use and appeal to them in a game-based learning context.

There are several examples of existing learning games which deal with topics from informatics and society. Ref [2] give an overview of studies on Internet learning games. Internet Hero follows several of J.P. Gee's learning principles [3] in presenting topics around the Internet for children aged 8

to 12 [4,5] to discuss the potential of learning games for teaching cyber security, including topics like malware, email and spam.

Cyberworld Adventure [6] and Net-Detectives [7] are games that teach safe Internet use to 9- to 12-year-old children. Anti-Phishing Phil [8] is an online game which explains how to protect yourself from phishing attacks. All three studies show positive impact on children's knowledge about the Internet. SimSafety [9] also deals with Internet security. The results of an earlier study on the game are documented in [10]. CyberCIEGE [11] is a resource management simulation that lets students understand the impact of security choices on an organisation. All of these references are examples of successfully translating topics from informatics and society into a game-based form, but there are few insights into how they can be integrated into school teaching and how to design game-based content in a way that appeals to school students. With regard to genre, Heinz and Law [12] looked at learning effects by game types. They saw an increase in learning effects with action games compared to other genres such as puzzle games. But this result has limited significance as the action game tested followed a behaviourist approach compared to the constructivist nature of the other games tested.

In an analysis of 21 cybersecurity games, Gestwicki and Stumbaugh [13] identified three different types of games; "those whose gameplay is not associated with cybersecurity education content (Type 1); those that integrate multiple-choice decisions only (Type 2); and those that integrate cybersecurity objectives into authentic gameplay activity (Type 3)." Gondree and Peterson [14] designed and deployed a board game for cybersecurity education. The main challenges they identify are: relevance of the game to the curriculum, appropriateness for and accessibility to the target audience, and how to best evaluate the impact of such a game. Control-Alt-Hack [15] is a card game about cybersecurity. A study with 14 teachers of 450 students indicates that the game helped raise awareness and changed the perception of cybersecurity topics of students. Likewise, SecurityEmpire [16], a digital game to promote cybersecurity education, showed the ability to raise awareness of issues around cybersecurity.

In terms of using game design as a teaching method, Kafai [17] documents the constructivist use of game programming and design with elementary school students to convey math problems to lower grade students. The benefits of aligning math problems with games programming have also been documented in [18]. There further are guidelines on how to use game design to teach and support computational thinking: low threshold and a high ceiling of challenges, scaffolding flow, enabling transfer, supporting equity among students, and systemic embedding; refs. [19,20] cite game design and development as an approach appealing to all genders, which teaches higher-order thinking and abstraction and which serves as an attractor to computer science education. These examples all address technical aspects of computing. Denner et al. [21] provide evidence that girls can learn computer science concepts through game development. Robertson [22] describes gains in storytelling competence of 11–12 year old learners through using game design. To our knowledge there are no examples of using game design for social issues in informatics.

In our project students created both board games and digital games. We follow the core research question: "How can game- and game design-based learning be used to teach topics from informatics and society and to increase the game literacy of secondary school students?" This further leads to sub-questions such as "Which learning contents do secondary school students choose on their own?", "Which kinds of games do they create to communicate these contents?", and "How much can this kind of project-based teaching contribute to learning experiences regarding informatics and society and game literacy?"

The educational project Sparkling Games [23] formed the basis for our analysis. It started with a detailed analysis of existing learning and mainstream commercial games. Students then conceptualised and developed games step-by-step to support teaching areas including copyright and intellectual property, privacy, surveillance, social media, and big data. The project was meant to transfer academic skills to students, who gained expertise in the areas of game design and serious games as well as in social science research methods intended to assess and reflect on their creations. Key results of the project included a collection of existing games supporting learning about informatics and society,

new games and game concepts developed by students, and bottom-up insights into how game-based learning can be used in schools. Sparkling Games strived to expand the potential of games as media for learning, reflection and for teaching media literacy. The presented paper will focus on the first step of the project, in which students identified examples of games with learning contents, and on the games created by students later in the project. We will present the results of a thematic analysis of the entries made by students into an online database and of the games they created, along with a critical reflection of the project's impact by the teachers involved.

We take a secondary school student-centered perspective on game- and game design-based learning in the area of informatics and society. From this perspective we present the following core results:

- a collection of learning contents and ways of delivery identified by students in commercial games;
- a collection of analogue and digital games created by students, and an analysis of which topics they chose and how these topics were communicated;
- insights into how project-based work with games and game design can raise awareness for topics from informatics and society;
- insights into how project-based work with games and game design can increase game literacy.

2. Materials and Methods

2.1. Informatics and Society

The choice of topics follows the computer science curriculum and the official guidelines for media education issued by the Austrian ministry of education. Coverage of topics revolving around informatics and society in schools is explicitly intended in the respective curricula. In the syllabus of the 9th grade, the following specific wording is found: "The students are supposed to learn about essential measures and legal basics concerning data security, privacy and copyright as well as to understand the effects of the use of technology on individuals and society" [24].

In the ACM (Association for Computing Machinery) computer science curricula [25] recommendations the following can be found: "While technical issues are central to the computing curriculum, they do not constitute a complete educational program in the field. Students must also be exposed to the larger societal context of computing to develop an understanding of the relevant social, ethical, legal and professional issues", and: "As technological advances continue to significantly impact the way we live and work, the critical importance of social issues and professional practice continues to increase; new computer-based products and venues pose ever more challenging problems each year." It can be argued that the process of recognising these problems and introducing them as a topic of discussion should start as soon as children have access to technologies, e.g., when they first own a smartphone. At the same time these "softer" aspects of technology can also be found in the Austrian school curricula [24] for informatics teaching cited above. Our own internal discussion within the project team resulted in the following list of topics, which define the informatics and society scope for the project:

- Cyberbullying,
- reliance on/dependence of technologies,
- identity theft,
- data security of banks, insurance companies etc.,
- privacy/voluntary disclosure of personal information,
- extortion malware,
- cybercrime,
- digital divide,
- hacking and critical systems (nuclear power plants, hospitals etc.),
- copyright,

- site blocking and internet censorship,
- digital rights management (restrictions on music, movies, e-books),
- lacking diversity in IT (fewer women, immigrants),
- state surveillance,
- corporate surveillance,
- accessibility of technologies,
- loss of jobs due to automation,
- ethical issues.

In fact, these topics are often severely disregarded in schools and instruction mainly focuses on technical skills and competencies. In the light of constant social change it is becoming more and more important to deal with sociopolitical issues in classrooms in a systematical and structured way. In recent years the spread of technical development has increased considerably. Hence, new areas of tension arise in society that are of major importance for everyday life. Questions concerning copyright and intellectual property, privacy and surveillance, social media and big data, digital vulnerability and the dependency of users have quickly evolved from side issues into central issues of sociopolitical debates. Consequently, the consideration of relevant topics in class is becoming more and more important. The project Sparkling Games addresses these issues that are difficult to integrate into instruction.

2.2. Project Context

Together with secondary school students, the project Sparkling Games investigated how concepts from the field of game-based learning can be used to develop learning methods and teaching materials. These methods and materials are supposed to enable the integration of the topic "informatics and society" into computer science classes as well as into other subjects, e.g., arts teaching. The project was funded by the Austrian Sparkling Science [26] funding scheme, which finances projects where schools and universities are supposed to collaborate. In our case this meant conveying how to use game design to model real world issues. The real world issues are informatics and society topics as outlined above.

The project goal was the design of learning games in the area of informatics and society by the participating secondary school students. The range of games created comprised board and card games as well as computer and console games. The participating scientists supported the students, observed the process, and evaluated the results. Thus, conclusions about successful and geared-to-the-target-group design of learning games can be drawn. Furthermore, the project team analysed if and how well the chosen approach of designing learning games is suited as a teaching method. The target audience of the created games are students in grades 9 to 13. An exhibition of the games at the game trade show GameCity in Vienna's town hall is the project's conclusion and highlight. A discussion of the project results between the participating and other interested teachers was conducted in this setting.

The project Sparkling Games encouraged an exchange of ideas and skills between the participating secondary school students and scientists. Expertise in the areas of game design and reflection upon as well as evaluation of games was imparted to the students. Also, valuable insights on designing learning games were gained. In contrast to conventional research approaches these insights were not formed by rating existing products—instead they arose directly from the target audience.

The timeline and key elements of the students' participation in the project were as follows:

- Participation in several workshops (introduction to the project and the subject area informatics and society; game design);
- creation of an online database comprising learning games and opportunities for learning using off-the-shelf games;
- responses to two online surveys dealing with informatics and society (at the beginning and end of the students' involvement);

- attendance at two project gatherings for all participating students (from three different schools);
- design of digital or board games in small groups;
- presentation of the games to other Viennese students and conversation about the design process at the Game City 2016, an annual trade show for digital games in Vienna, Austria.

2.3. Learning Effects

A survey was designed to provide the project team with insight into the youths' knowledge on and attitudes towards informatics and society [1]. The first set of the survey was conducted at the beginning of the project and comprised 42 questions; the second set was conducted after the students had finished their task of designing a learning game themselves (i.e., at the end of the project from the students' point of view) and consisted of 28 questions, all of which had already been asked in the first set. Thus, the survey shows if (and in what direction) the participating students' attitudes and awareness have changed during the course of the project. The pre-survey was completed by 57 students (30 male/27 female) and the post-survey by 47 students (22 male/25 female). There was a control group for both sets of the survey. The sample sizes there were 64 (39 male/25 female) for the pre-survey and 56 (35 male/21 female) for the post-survey. The control group consisted of school classes of the same type and grade as the project participants (namely the students designing learning games). We intended to detect whether the year-long involvement of the participating students with project-based learning confronting them with informatics and society topics when designing their games would result in them learning more about informatics and society than regular students. The survey included open questions such as "Which invention(s) should informatics/computer science make by all means?" and multiple-choice questions such as "Cyberbullying is—a very big problem—a big problem—a small problem—no problem".

However, in general there were no statistically significant differences between the participants and the control group. Still, there is evidence by tendency that the project participants' awareness for socio-technological issues was being raised: for example, security and privacy online were considered more important; also, internet expertise and time spent online were assessed more realistically after the year-long project participation [1].

2.4. Sample

The project ran for one school year, from September 2015 to June 2016. We worked with three different secondary schools in Vienna, Austria; one grammar school (gymnasium), one trade school and a technical school. There were large differences in the learning environments of the schools participating in the trials (in terms of the technology available and the knowledge of the student base), which presented significant challenges. However, through game design workshops, presentations and discussions, it was possible to partially offset these differences.

From our own observations and from the teacher group discussion (see Section 2.5), we know that there was little to no game design experience, with only students from the technical school having small prior knowledge in that regard. From the workshops we also know that there is a broad range of different experience with playing games, ranging from very dedicated video game players, to casual players, to students who have almost no experience with playing games. We also saw clear gender differences, with girls reporting much less experience with playing games than boys. Also, all students from the technical school (which were almost exclusively male) made digital games while none of the others did, although all were given the option to create a digital game.

Four teachers were involved with the project. Overall, there were 60 to 70 students (the number fluctuated due to drop-ins and -outs over the school year) who participated in the project in groups of two to five students. To further a culture of collaboration and autonomy, the students formed the groups on their own during the workshops and within the respective participating classes. We held four workshops separately for each class, and there were two large meetings where all classes took part and together discussed the concepts and resulting games; 55 entries were made into the game

database, and a total of 18 games (11 board games and 7 digital games) were created over the course of the project.

2.5. Methods

This paper relies on three sources of qualitative data, each evaluated by multiple coders:

- a qualitative thematic analysis of the database entries made by students (3 coders);
- a coded categorisation of the games designed and made by students (2 coders);
- a qualitative semi-structured group discussion with teachers (4 coders);
- observation notes and informal data collected by the project team.

The database entries were evaluated using thematic analysis [27]. Three researchers independently identified categories that were later discussed and merged. The creation of games by students was based on Høbye and Löwgren's "research-through-explorative-design" approach [28]. This approach is shaped by three essential components, which also refer to works by [29,30]: "(1) a focus on 'sketching with technology', [. . .] is used to explore issues of behavior and enactment (as opposed to envisionment) [. . .]; (2) experimentation in the sense of making and trying out prototypes or partial prototypes is the primary mode of working [. . .]; and (3) the goal of the experiments is to grow an understanding and a sensibility for the experiential qualities of embodied interaction's materials and ensembles" ([28], p. 33).

The games were later played by the research team in a reflective manner akin to Aarseth's concept of playing research [31]. Then, two researchers discussed the games and developed a categorisation together. A group discussion was held with four teachers and four researchers of the project team. The group session was audio-recorded and a mind map was made and discussed during the session. The session was evaluated using thematic analysis to refine the categories established in the mind map.

All the qualitative data was interpreted in a process-based and collaborative team analysis, where meaning was reciprocally negotiated until all opinions and perspectives of the coders had been considered and satisfied.

Furthermore, we rely on informal data collected as notes of the project team during workshops and as feedback from teachers over the whole course of the project.

3. Results

3.1. Database

In the presented study, high school students were asked to look for examples of the topic informatics and society or other interesting learning contents in games (board games as well as video games; database task description: "Find examples of analogue and digital games, which help players to learn about something in an interesting manner. You can look for games which discuss informatics and society topics, but you can also include other games. Please make a new entry into the database for each learning experience you want to describe. A game can have more than one learning experience. If you make a new entry, please check that it is different from what already is in the database. Overall please make entries for three different games"). The task was chosen to raise students' awareness for how learning through games can work. As a starting point for their research, we provided a small package of commercial mainstream and serious games (as can be found on dedicated portals such as [32,33]). In the first workshop, we discussed definitions of both games in general and of learning games in particular. Furthermore, we discussed the exemplary list of informatics and society topics with them (see Section 2.1). They documented the games they came upon in an online database developed specifically for the research project (Figure 1). Database entries could refer to whole games covering the respective topic or just segments of common games. Regarding games dealing with more than one topic, we encouraged one database entry per topic. The students were prompted to accurately describe how the selected game addresses the topic/learning

content they found appealing and illustrate it utilizing videos and pictures. Also, we requested them to use tags to organize the topics in question. This is similar to how learning games have been analysed academically using the learning mechanics–game mechanics (LM-GM) framework [34].

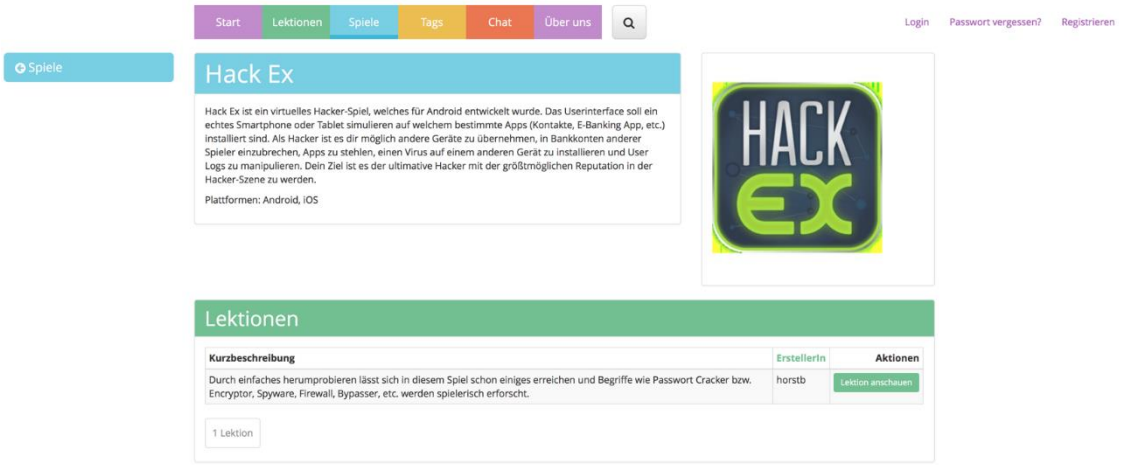


Figure 1. Entry for the game "Hack Ex" in the Sparkling Games database.

We conducted a thematic analysis of 55 database entries altogether (see Table 1 for an overview). Three researchers independently identified categories that were later discussed and merged. The most frequently recorded game genres are open world and shooter (10 mentions each), simulation, action adventure, jump'n'run (6 mentions each), racing and strategy (5 mentions each). Board and card games, respectively, are hardly mentioned (4 times, in comparison to 51 mentions of digital games). Mobile games (6 mentions) and casual games (4 mentions) are of surprisingly little importance. The topics most often identified in the recorded games are war (15 mentions), society (13 mentions) and morality or moral decisions (13 mentions), followed by fantasy (8), history (7), politics and economy (5 each). However, when given the task, the students were explicitly challenged to find example games for informatics and society topics, and there are only few mentions of such. We conclude that the threshold to solving the task was too high, considering the students' relatively low knowledge about game design as well as informatics and society topics. The informatics and society topics mentioned are hacking (5 mentions), privacy, informatics know-how, artificial intelligence/conscious machines (2 mentions each), cybercrime and robotics (1 mention each). Finally, we analyzed the mechanics used to convey the topics/learning contents covered above. Here, acting strategically, competition (16 mentions each) and cooperation (15) are most significant; the obvious importance of playing within a social context, either together or against each other, is remarkable. A game's narrative (13 mentions), repetition and taking another's perspective (11 mentions each) are of relevance, too. Other commonly quoted mechanics include a dystopian game setting, systemic learning, learning through trial and error (8 mentions each), acquiring factual knowledge (7) and exploration (6).

Table 1. Overview of the analysis of genres, topics and mechanics in the Sparkling Games database.

Genre	Count	Topic	Count	Mechanic	Count
Open World	10	War	15	Acting strategically	16
Shooter	10	Society	13	Competition	16
Simulation	6	Moral decisions	13	Cooperation	15
Action adventure	6	Fantasy	8	Narrative	13
Jump 'n' Run	6	History	7	Repetition	11
Moble	6	Hacking	5	Taking another's perspective	11
Strategy	5	Economy	5	Trial & Error	8
Racing	5	Politics	5	Systemic learning	8
Survival	4	Sports	4	Dystopia	8
RPG	4	Crime	3	Acquiring factual knowledge	7
Casual	4	Videogames	2	Exploration	6
Board-/Card Game	4	Privacy	2	Empathy	4
MMORPG	3	Informtics know-How	2	Acquiring practical knowledge	2
Adventure	2	Artificial intelligence/conscious machines	2	Logical reasoning	1
MMO	2	Resources	2	Satire	1
Trading Card Game	2	Sustainability	2	Consteained scope of action	1
Puzzle	1	Consumerism	2	Singing	1
Mussic Game	1	Cybercrime	1		
Beat'em Up	1	Robotics	1		
		Urban planning	1	Informtics and society topics	
		Music	1		
		Riddles	1		

3.2. Games

Overall, the students created 18 games, 11 board games and 7 digital games, one of them a virtual reality game. Board games were started in school and finalised using materials provided during a dedicated board games workshop. The digital games were created as part of a year-long technical school project, using either the Unity or Unreal 3D game engines.

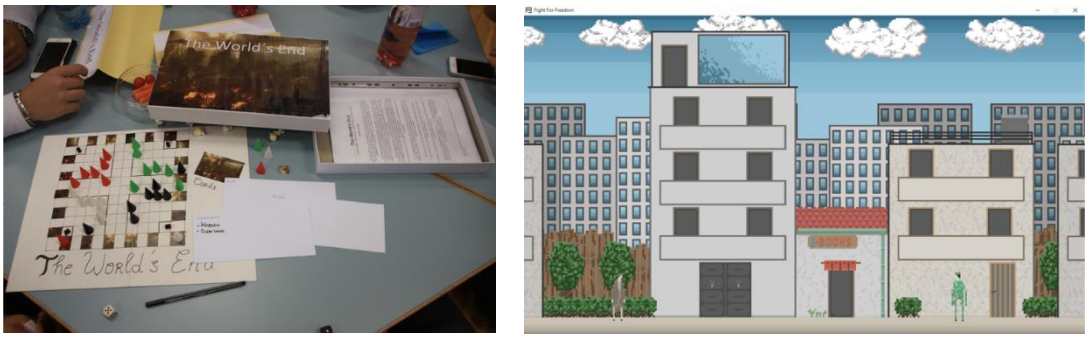
In the following, we will first describe the genres and game mechanics of the games (see Figure 2 for examples) before discussing the embedded informatics and society topics and associated learning mechanics. The genre and mechanics terms for analysing the board games are inspired by the categories used by the vastly popular board game index site BoardGameGeek [35].

The 11 board games mostly belonged to the genre categories of trivia (6 occurences) and objective race (6) games. Objective race games are board games in which the player to first reach a finish line/goal on the board wins. Many games also contained elements of both the trivia and objective race genres. Other less popular genres included simulation (1), strategy (1) and word games (1). The most used game mechanics in the board games were roll/spin and move (7), meaning to roll dice and move a piece accordingly, and linear movement (7) along a path on the game board. Other used mechanics included cooperative play (2) and dare or die (2), where players must perform a dare assigned either by other players or randomly to avoid losing the round.

The 7 digital games were spread across different genres and contain elements of jump'n'run games (2), role-playing games (2), first-person horror games (1), adventure games (1) and beat'em up games (1). The most used mechanics of the games include fighting (6), platforming (4), interactive narrative and dialogues (3), and loot and levelling (2).

Four of the 18 games did not make any significant connection to informatics and society topics despite students being prompted to do so. In the remaining 14 games the central themes were security

(8), privacy (7), technological literacy (5), social media (4) and hacking (4). Other themes included surveillance (3), copyright (3), and cyber bullying (3). The game mechanics used most to convey those themes were competition (8), narrative (6) and prompting knowledge (6). Other mechanics included creative play (3), cooperation (2), letting players take a different perspective (2) and dystopian game worlds (2).



(**a**) (**b**)

Figure 2. Student-created games from the Sparkling Games project. (**a**) The World's End is a tactical board game for two players, where they try to breach each other's firewall; (**b**) in the digital point-and-click adventure game Fight for Freedom players mostly work out how to orient themselves in a future society where analogue and printed media have ceased to exist.

3.3. Teacher Evaluation and Informal Data

The teacher evaluation was held as a two hour-long group discussion, where the four participating teachers critically reflected on the course of the project with four researchers of the project team. Due to a high workload on students in the end of the semester, we could not ask them for feedback directly, but used the teachers as proxies for student feedback. Furthermore, the following insights implicitly consider the observational notes and informal data collected over the course of the project as they served as inputs for the group discussion. The main discussion points were:

- There was only a limited increase in the level of knowledge students had of topics concerning informatics and society. However, there was a higher degree of sensitisation for these topics than previously, in particular towards data privacy, cryptography, password security, cyber mobbing and age-inappropriate content. This is of particular importance as those topics are not embedded in the students' regular curricula. These results are further confirmed by a pre- and post-test study with the participating students [1].
- We saw a clear increase in game design competence as a result of game design workshops and actively creating games. Showing the games at the GameCity fair was particularly motivating in that regard. For students who previously did not play a lot of games, we also saw an increase in general game media literacy.
- There was a lot of interaction among the students. The three schools had very different groups of students, and all were interested in interacting with students from the respective other schools. Also, students gave each other constructive feedback on the games they created.
- We learned several lessons on how to better embed project-based teaching in schools; instead of spreading out sessions and workshops over a full year, it would be better to have more intense successive project days or a whole project week. It is hard to find incentives for students to work on their projects aside from scheduled sessions because they already have a very high workload. Teachers need more tools or indicators to judge the progress of students during project-based work.
- The workshop and hands-on approach of the project were very well received by students. Talking to game design experts and academics helped motivate them. Students particularly liked the large gatherings where all three schools were present.

- To have a sustained impact, the resulting games and the applied game design methods need to be contextualised with the curricula of the involved school subjects (informatics and arts) and should be described as ready-to-use teaching modules, complete with instructions for preparation and reflection.

3.4. Summary

Students fist identified learning contents in commercial off-the-shelf games. The most popular genres were open world games and shooters, followed by simulation, action adventure, jump'n'run and racing games. The topic from informatics and society most identified in those games was hacking. But students focused more on other more general topics. The most mentioned topics were war, society and moral decisions. The mechanics most frequently identified to convey these topics were acting strategically, competition and cooperation. Students then created their own digital games and board games. Most board games fell into either or both the objective race and trivia genres. The digital games encompassed multiple genres such as jump'n'run and role playing games. Game mechanics focused on fighting, platforming and dialogue. The topics most frequently addressed in the students' games were security, privacy, social media, hacking and technological literacy in general. In the teacher evaluation, which was also used to capture the perspective of students, we confirmed that there was little increase in knowledge about topics from informatics and society, but that the project brought a high degree of sensitization for those topics. We also saw a clear increase in game media literacy and game design competence. Overall, we further learned about the social importance of interaction among students in project-based teaching, the need to condense sessions and the need to tie project-based teaching to curricula.

4. Discussion

Summarised, we successfully applied a project- and game-based approach to teaching informatics and society topics. While we could not show significant knowledge gains in this area, we measured an overall increase in awareness for topics from informatics and society and gains in game media literacy and game design competence. This is in line with the impact of learning games, which also raised awareness of cybersecurity issues [15,16]. The approach of hands-on workshops and creating games in a bottom-up process were well received by teachers and students alike, but a better embedding in the curricula and the schools' organisational structure was desired. This corresponds to the challenges identified by [11,19]. As evidenced by the presented project, project-based teaching in the classroom is preferable to traditional approaches when it comes to complex issues such as the ambivalent relation between technology and society. Independent student projects offer a combination of creative freedom, social learning and mutual feedback, and thus can also be appropriate for other challenging and interdisciplinary topics, e.g., diversity. Game design and informatics and society topics did not mutually distract from one another. Overall game design did get enough attention as it also was the method applied by students, while informatics and society topics, as the theoretical subject matter, could have gotten more. But this is less a matter of game design detracting attention than a matter of overall lack of time.

The most prominent topics identified in the database were more general and only loosely related to informatics and society: war, society and morality or moral decisions. The topic most identified that relates to informatics and society was hacking. In the created games, the central themes were security, privacy, technological literacy, social media and also hacking. These areas correspond to the foci picked up by previous learning games in that space [2,4,6–12,14–16]. Both in the examples discussed in the related work and in the students' games, security is the most prominent area. The lack of informatics and society topics in the database is understandable–evaluation results showed that students had very little base knowledge and had to be sensitised for the existence and relevance of these topics.

The most popular genres in the database were open-world games and shooters, but none of the digital games fell into these genres (there, jump'n'runs and role-playing were the most prominent

genres). The simple reason for this was that the open-world and shooter genres demand much more resources and time in development. Heinz and Law's [12] good learning results with action games might also relate to the genre preference towards shooter and open world games we saw. The most used mechanic in student-designed digital games was fighting. Board game genres were very simple with most using either trivia games and/or objective race games as the frame for their creations. Game mechanics that convey learning contents identified by students heavily focused on social interaction (competition, cooperation), and also included learning mechanics (acting strategically, change of perspective) similar to those described by J.P. Gee [3] and applied in our own previous work [4]. The importance of interaction in both game-based and project-based learning was also confirmed in the group discussion with the teachers.

Overall, none of the created games qualified as a dedicated learning games; instead, the contents were embedded in more or less regular game concepts. Aside from trivia games, the students partly struggled to meaningfully integrate the learning concepts into their games. Positive examples include games in which the narrative of the game world educates players about informatics and society topics. The effort put into the games and the subsequent quality of the student creations also varies greatly. About two thirds of the created games show that enough effort was put in. In the digital games in particular, some of the students also overextended themselves on too broad a scope for their games. Following the three types of cybersecurity games outlined by [13], many of the board games fell into category 2, where contents were represented as multiple-choice trivia questions, but a lot of the other games succeeded in integrating the topics into the narrative and actual gameplay (type 3).

Overall, the genres of the games in the database more seem to show what genres students like to play rather than what they deemed useful to convey learning contents. In terms of genres of the created games, we noticed that students did not pick genres and mechanics that are particularly well suited to conveying the respective learning content. Board games most relied on trivia games, and genres of the digital games more seemed to reflect the technical interests of the respective student groups.

Outlook

Many approaches to using technology in learning are top-down. Technological solutions are applied in schools and their impact is tested with students. Our results stem directly from a bottom-up approach with the target audience. They enable us to better orient the design of future learning games towards genres and concepts identified by students in games they like to play, and which they like to use when creating their own games. We could show that a project-based approach is suitable for integrating informatics and society topics into school teaching, but we also saw the need to first raise awareness for issues from that area. Future learning games can build on these insights by first sensitising players to issues and later incorporating more knowledge-oriented contents. Drawing from the experience from the presented project, we also learned that intense project weeks might potentially be better suited for project-based teaching than spreading out sessions over a full year. We further learned that project-based teaching needs to be closely aligned with the curriculum and needs to accommodate requirements from daily practice in schools, such as good planning of resources and time, measures of success for teachers, and clear instructions for preparatory and reflective work before and after such an intervention. Project-based teaching also provides a broad educational framework and opportunities beyond its primary purpose, as in our case we could also see increases in game design competence and game media literacy.

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