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Using Non-Digital Games to Enhance Learning in Interdisciplinary Approaches to Informatics

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DIPLOMA THESIS

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in

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by

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to the Faculty of Informatics

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Wien, 3. März 2025

Shuyin Zheng

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Kurzfassung

Game-based Learning (GBL) ist ein interdisziplinäres Forschungsfeld mit wachsender Popularität. An der TU Wien wird es in der Lehrveranstaltung "Denkweisen der Informatik" im Bachelor-Studiengang Informatik eingesetzt. Dort werden Brett- und Kartenspiele, die Themen der Lehrveranstaltung adressieren, von erstsemestrigen Studierenden gespielt, die danach über die GBL-Aktivität, als Teil der Kursarbeit, reflektieren.

Frühere Anwendungen von GBL in diesem Rahmen waren überwiegend erfolgreich und haben gleichzeitig Verbesserungsmöglichkeiten aufgezeigt. In dieser Arbeit werden die Spiele analysiert, die in der nächsten Iteration von GBL im Kurs verwendet werden sollen, und es werden für jedes Spiel spezifische Reflection Prompts erstellt, die das Lernen durch Spiele verbessern sollen, indem der Reflexionsprozess der Studierenden dadurch unterstützt wird. Darüber hinaus wird in dieser Arbeit untersucht, wie Studierende von DWI den Lerneffekt der Spiele, der GBL-Aktivität und GBL als Methode wahrnehmen.

Für die formale Analyse der Spiele werden zwei etablierte Frameworks für Lernspiele verwendet und mit Design-Artefakten kombiniert, die von den Designer:innen der Spiele zur Verfügung gestellt wurden. Prä- und Post-Workshop-Fragebögen werden designed und die Ergebnisse daraus analysiert, um die Antworten der Studierenden zu diskutieren.

Die Ergebnisse dieser Arbeit können als Designüberlegungen für zukünftige Lernspiele und zukünftige GBL-Aktivitäten dienen, um das Lernen in GBL-Aktivitäten allgemein, und ebenso im Informatikstudium im Besonderen, zu verbessern.

Abstract

Game-based learning (GBL) is an interdisciplinary field of study that has been growing in popularity. At TU Wien, it is used in the course "Denkweisen der Informatik" (eng.: ways of thinking in informatics) in the bachelor's program of Informatics. There, non-digital games that address topics of the course are played by first-year students. These students then reflect on the GBL activity as part of the course work.

Past applications of GBL in this setting have been mainly successful, and at the same time revealed potential areas for improvement. This thesis analyzes the games to be used in the next iteration of GBL in the course, and creates reflection prompts specific to each game, which should enhance learning through games by supporting the students in the reflection process. Additionally, the thesis investigates how students of DWI receive the learning impact of the games, the GBL activity, and GBL as a method.

Two established assessment frameworks for educational games are used to analyze the games formally, combined with design artifacts provided by the designers of the games. Pre- and post-workshop surveys are designed and the results analyzed to discuss students' responses.

The results of the thesis can serve as design considerations for future games with a learning purpose, and future GBL activities, enhancing learning in GBL activities overall, as well as in Informatics education specifically.

Contents

CHAPTER 1

Introduction

1.1 Problem Statement

In Informatics Education, most of the course content focuses on the technology side of the discipline. However, Informatics and technology in general are embedded in society and in constant exchange with other areas of life and thus with diverse academic disciplines. Therefore, teaching various different approaches to problem-solving in Informatics is a valuable part of the curriculum.

At TU Wien, the Bachelor's program of Informatics includes a mandatory course for students in their first year of studies, called "Denkweisen der Informatik" (english: Ways of Thinking in Informatics; henceforth abbreviated as "DWI"). This course introduces students to different approaches to Informatics, called "Ways of Thinking" (henceforth abbreviated as "WoT"): Scientific Thinking, Computational Thinking, Design Thinking, Responsible Thinking, Critical Thinking, Criminal Thinking, Policy Thinking, Creative Thinking. The goal of the course is to enable students to view Informatics problems from different perspectives, learning (inter-)disciplinary approaches to problems they may encounter later in their lives and careers. [8]

DWI is offered every winter semester and provides various formats of activities that supplement the lecture content. In winter semester 2023/24, one of the activities utilized Game-based Learning (GBL) as a method: In a workshop format, students played two games about one WoT, and reflected on their experience and learning process in a written form. The games were chosen from a list provided by the lecture team and contain digital as well as non-digital games. Among these games, there were five non-digital games that were specifically designed for this purpose in summer semester 2023, in the course "Gameful Design". The game designers were students of the master's program Media and Human-centered Computing at TU Wien and advanced students of the bachelor's program Informatics at TU Wien. The results of the first iteration of using GBL in

DWI has been mostly successful [13] [25]. While students both enjoyed the activity and reported that the activity has enhanced their understanding of the WoTs, more and detailed evaluation of GBL's learning impact is needed. Furthermore, the reflection process after the students have engaged with the games has been identified as an area for improvement, which can positively impact the learning outcome.

For the next iteration of GBL in DWI, one of the five already used non-digital games was retired, and four additional games were chosen out of several created in summer semester 2024 by a new cohort of students of Gameful Design, among them master's students of the program Media and Human-centered Computing at TU Wien, and students from the Teachers Education program at Universität Wien. Adding to these nine games, five non-digital games, which are adaptations of existing games or created by students outside the Gameful Design context, are also used in DWI in winter semester 2024/25, leading to 14 games in sum. Additionally, the workshop format underwent changes.

In order to further improve the GBL activity and the evaluation thereof, the thesis will first analyze each game in regard to their learning effects, and create reflection prompts individual to each game that invite and guide students to better reflect about the games themselves and in connection to the lecture contents. Through the use of pre- and post-workshop surveys, insights in students' perception of the process will be gained and analyzed. The research questions are therefore:

- RQ1: Which reflection prompts could help students better understand the connection between the games and the Ways of Thinking, and therefore enhance the learning process of the Game-based Learning activity in DWI?
- RQ2: How do students of DWI receive the learning impact of the games, the Game-based Learning activity, and Game-based Learning as a method? What can be learned from their responses?

1.2 Aim of the Work

All 14 non-digital games used in winter semester 2024/25 are analyzed in regards to their respective learning effects, how they can best be connected to the lecture content of DWI, and what reflection prompts could enhance students' reflection after playing the game. The reflection prompts are where the results of the analysis are implemented to an updated iteration of GBL in DWI. These reflection prompts are embedded in surveys that serve as additions to the game workshops, which are all part of students' course work in DWI. The outcomes of the student surveys are then analyzed to answer Research Questions 2. In the end, the thesis identifies challenges and opportunities in GBL using non-digital games in Informatics education, and offers design considerations for future games with a learning purpose as well as for future GBL activities. The outcomes can be applied to future design processes for serious games, as well as to implementations of GBL in other Informatics or non-Informatics programs in higher education – all in

all advancing the field of GBL, and enriching (inter-)disciplinary teaching in higher education.

1.3 Methodology

This thesis uses the following methods to address research questions.

1.3.1 Literature Review

First, a literature review is conducted. Its results constitute Chapter 2 of the thesis.

1.3.2 Games Analysis

The 14 games used in the workshops that are topic of the thesis are analyzed and the results thereof presented in Chapter 3.

The analysis uses design artifacts and documentation created by students while designing the game, for the games designed by students of "Gameful Design". In the case of the other games, the analysis relies on the instructions of the games, and, if the games' designers can be reached easily (which is the case for some of them, who frequent the same institute at the university as me), they are asked to elaborate on aspects that were unclear, in an informal way. In addition to analyzing what students themselves intended the games to be, two established serious games analysis frameworks are used to analyze the games formally: Arnab et al.'s learning mechanics-game mechanics (LM-GM) model [2] and Mitgutsch and Alvarado's Serious Game Design Assessment (SGDA) framework [15].

With the SGDA framework [15], the authors propose that for a serious game to be effective, it is crucial to design a cohesive and coherent game system. Such a system is identified in its inter-related elements: (1) **Purpose**: what is the purpose of the game intended by its designers?; (2) **Content & Information**: what information is presented in the game, and how is it presented?; (3) **Game Mechanics**: what are the rules and goals of the game, what does the learning curve look like?; (4) **Fiction & Narrative**: what is the plot of the game, what are the characters like?; (5) **Aesthetics & Graphics**: what is the graphical setting of the game, how is the world visualized?; (6) **Framing**: what is the broader topic of the game, which kind of play literacy is required to play it?; and, finally, (7) **Coherence and cohesiveness**: do all game elements fit together, creating a coherent and cohesive game system? By using this framework, a game is analyzed not only in these elements distinctively, but also in how they reflect the proposed impact or aim of the game, and the way the elements relate to each other, supporting the overall cohesiveness of the game system.

On a more concrete level, Arnab et al.'s LM-GM model [2] is an model for analyzing serious games in their detailed mechanics. It focuses on specific game mechanics, distilled from game design theories, such as role play, movement, status. The game mechanics are

each mapped to concrete learning mechanics, which are based on educational theories, e.g., guidance, modelling, responsibility. Additionally, the model offers a classification of game mechanics and learning mechanics based on the 2001 revised version [1] of Bloom's taxonomy [4].

Bloom's taxonomy [4] is a well-established framework for classifying, analyzing and discussing educational objectives. The revision in 2001 [1] transforms the taxonomy into a 2-dimensional framework, with the knowledge dimension as one axis, and the cognitive process dimension as another. The knowledge dimension consists of *factual*, *conceptual*, *procedural*, and *metacognitive knowledge*; the cognitive process dimension of the revised taxonomy consists of *remember*, *understand*, *apply*, *analyze*, *evaluate*, and *create*. The categories of each dimension are ordered hierarchically, increasing in complexity, although the categories can overlap one another. In Arnab et al.'s LM-GM model [2], the classification based on "thinking skills" refers to *retention*, *understanding*, *applying*, *analyzing*, *evaluating*, and *creating*. While it slightly differs from the wording of Krathwohl [11], these categories can be directly mapped to the cognitive process dimension as defined by Krathwohl.

1.3.3 Qualitative and Quantitative Data Analysis

Pre- and post-workshop surveys are designed based on the previous iteration of GBL in DWI, and the outcomes of the games analysis. The structure and content of these surveys, as well as the reflection prompts for each game, are presented in Chapter 4.

The results of the surveys contain quantitative and qualitative data. The quantitative data is based on the responses to Likert-scale questions. The responses are grouped by characteristics of the responses, as well as of the responding students. The medians of these response groups are used to visualize and discuss the outcome. Additionally, results from winter semester 2023/24's survey for the four games used in that iteration that were continued in this semester are used for comparison. In order to complement the quantitative data analysis, qualitative data from the survey responses are also analyzed using Thematic Analysis as coined by Braun and Clark [6]. These analysis results are presented in Chapter 5.

CHAPTER 2

State of the Art

2.1 Game-based Learning

Game-based Learning (GBL) is a field that has been growing in popularity over the last few decades, finding usage in various educational contexts [5] [22] [21]. Main arguments for GBL are that games provide motivation, engage players through different features and situated contexts, can adapt learning content to learners, and allows for "graceful failure" in an otherwise more stressful learning setting [18] [21]. In their systematic literature review of games and simulations in higher education, Vlachopoulos and Makri [22] identified three main areas of learning outcomes: Cognitive (e.g., knowledge acquisition, perceptual skills), behavioral (e.g., social skills), and affective (e.g., motivation and engagement). In Nadolny et al.'s study on characteristics of GBL [16], the authors discussed learning games in their primary characteristics (Assessment, Immersion, Interaction, Learner Control, Learning Support, Narrative), mapped to distinct categories of learning games (Leveled games, Problem solving games, Open-world multiplayer games, Immersive multiplayer games); and their secondary characteristics, associated with key game features.

In the case of higher education, Subhash and Cudney [21] found in their review that a majority of GBL in higher education studies were conducted in the field of computing. In Computer Science specifically, Battistella and Wangenheim's systematic review [3] showed a wide use of both digital and non-digital games for Informatics topics, the most popular topics being software engineering and programming fundamentals. Johnson et al. [9] reviewed digital games for Informatics education and also found an overwhelming majority of the games to be on the topic of software development fundamentals. Together with Battistella and Wangenheim [3], the focus on technical aspects in educational games for Informatics is apparent.

2.2 Non-digital Games in GBL

Compared to digital games, non-digital games seem to be under-utilized in GBL, despite their historical presence in education [14] [16].

In Sousa et al.'s systematic literature review of non-digital games used in GBL [20], 45 studies from 2012 to 2022 were assessed. 23 of the games were about social sciences, 8 were Informatics-related. 24 of the reviewed studies were in a higher education context. Most reviewed studies reported positive learning outcomes, many analogous to digital games for GBL. Characteristics specific to non-digital games that were positively mentioned include the social, flexible and inexpensive nature of the games, as well as lower barriers in engaging with the games. The authors pointed out the potential in non-digital games to promote soft skills, in particular communication and collaboration skills. Lastly, the review highlighted a "lack of congruence between game systems and what is intended to be taught, with these contents being much more associated with the game theme than with its mechanisms and dynamics" [20, p. 10].

Maratou et al. [14] reviewed studies on non-digital games used in higher education GBL and found that quantitative analysis of post-game assessment, mapping of learning outcome, and inclusivity measures within the game were areas in which the studies were lacking. The authors also conducted expert interviews, which highlighted the strength of non-digital games in teaching social skills and developing creativity. One of the main challenges that arose from the study, which can also often be found in studies on digital games in education, is that teachers find it difficult to ensure learning *through* gameplay instead of GBL being an addition to the learning process.

2.3 Challenges in Designing for GBL

Simply using games in an educational context does not guarantee success. Westera [23] disputed popular positive claims about GBL, cautioning against relying on the belief that utilizing games would automatically increase students' motivation, highlighting that educational games should offer the right amount of challenge (which in itself is, again, hard to achieve) instead of focusing on being purely engaging. This desired balance between engaging game elements and effective learning effects is the core challenge of designing games for GBL.

Games used in GBL often focus on reviewing and reinforcing learning content, and at the same time are found to be lacking a grounding in instructional theory and game design theory [3] [5] [16]. Nadolny et al. [16] emphasized that researching games for GBL calls for reporting not only on the games themselves, but also on their design. Additionally, utilizing GBL not only requires suitable games. Preparation, scaffolding, debriefing, and assessment, for instance, are contributing factors to a successful implementation of GBL [12].

2.4 Reflection in GBL

Westera [23] pointed out that the often desired state of "cognitive flow" might conflict with learning. Cognitive flow describes the cognitive state in which players are fully involved and concentrated in a game, losing sense of time and fatigue. While this might indicate successful engagement of the player, it does not allow time, room and cognitive capacity to reflect about the content of the educational game. Similarly, Khaled [10] suggested that games that maximize immersion at the same time minimize room for reflection, and advocated for Reflective Game Design.

The Reflective Game Design agenda by Khaled [10] describes how conventional game design qualities can be de-emphasized in favor of more reflective qualities: (1) Questions over answers: games should not be about providing clear answers or "correct" solutions to complex problems, but instead provide a frame for players to explore and re-imagine problems presented to them; (2) Clarity over stealth: The learning aspects should not be hidden from the players – instead, players should be seen as an audience that welcomes the learning experience in connection with games, and be provided with information they need to contextualize the game experience with what is outside the game; (3) Disruption over comfort: Intentionally designed disruptive and uncomfortable moments can challenge the players to question the status quo and explore alternative ways of thinking about issues; (4) Reflection over immersion: In contrast to commercial games, educational games are not about escapism, but should consciously remind players of the framing of the game and the experience, in order to trigger deeper reflection.

The safe environment of games allows trial-and-error, which also might counteract thoughtful engagement with the learning material. When after playing, the memory of the play experience is what remains instead of deeper reflection, the safe environment of the game has rendered the learning elements irrelevant [10] [23].

It becomes evident that in addition to the play activity, instructors should provide sufficient time and opportunities for reflection, in-depth understanding, and self-evaluation to the students. Cantoia [7], for instance, suggested a design framework that encourages reflecting around the playing process. Before the game, students should reflect on their own beliefs and abilities in regard to the topic of the GBL activity, the teachers then define the main objectives of the activity together with the students. After playing the game, learning outcomes are assessed and reflected on as a solo and/or group activity.

2.5 Research Gap

In summary, GBL is a field as diverse as the contexts in which it is being used. In order to reap the benefits of the method, it is important to not only have well-designed games, but also to provide a process around playing the games that allows and, at the same time, encourages students to reflect about the GBL activity.

DWI provides a unique setting where students-designed games for specific course topics are played by students. These games are grounded in game design and instructional theory,

which is a rare occurrence among many games for GBL. They also have various approaches to Informatics as a topic, compared to the majority of games in Informatics education that focus on programming and software development fundamentals. Additionally, the non-digital form of the games can make up for some shortcomings of digital games and introduce new challenges. It is, either way, a valuable addition to the body of GBL research that has been lacking on the side of non-digital games.

By analyzing the games with established frameworks and creating reflection prompts that specifically target the learning effects and learning content of each game respectively, this thesis provides a new practical approach to enhancing learning through games. Embedded in the setting of a course teaching various different approaches to Informatics in higher education, the thesis itself is interdisciplinary and not only adds to the understanding of GBL application, but also to game design, interaction design, and Informatics education.

CHAPTER 3

Analysis of Games

In this chapter, the 14 games used in the games workshops of DWI in winter semester 2024/25 are analyzed. Table 3.1 shows Ways of Thinking (WoTs) and the games that are used in their context.

Way of Thinking	**Game 1**	**Game 2**	**Game 3**
Scientific Thinking	Pick me, please!	Sciendo	Keywords Memory
Computational Thinking	Robo Rumble	Finity!	Keywords Memory
Design Thinking	Wicked Inventions	Form Follows Function	Keywords Memory
Responsible Thinking	Morality Lab	Data, Privacy, Identity	Keywords Memory
Critical Thinking	Fehlschluss	Pick me, please!	Keywords Memory
Criminal Thinking	OfficeWars	Cyber Siege	Keywords Memory
Policy Thinking	The Policy Maker	Data, Privacy, Identity	Keywords Memory
Creative Thinking	TaleCrafters	Form Follows Function	Keywords Memory

Table 3.1: Ways of Thinking and their corresponding games.

3.1 Pick me, please! (Scientific & Critical Thinking)

Pick me, please!, designed for 3-5 players, addresses both Scientific Thinking and Critical Thinking by putting the players in the roles of scientists pitching their research projects for funding, and a policy maker who makes funding decisions based on their personal biases. This game was created by Thibault Borde, Filip Hörtner, Raphael Schimmerl and Annamaria Staubmann in "Gameful Design", summer semester 2024, and partly redesigned by the lecture team of DWI.

3.1.1 Game Description

One player is the funding body, the others play as researchers. The funding body first draws three secret biases out of a pool of 18, and assigns each of them one color. There are categories of biases: appearance (e.g., loves ties), topic (e.g., social engagement), and presentation style (e.g., always smiling). The researchers' task is to make pitches for research projects based on a previously defined topical category. The pitch should contain a research goal, methods, and why the proposed project is important. Researchers should also use accessories to alter their appearance, and adjust their presentation styles to what they think the funding body prefers, as prescribed by their secret biases.

After the presentation, the funding body player gives colored clips that correspond to the bias covered to the researcher. After all presentations, the researchers may discuss their thoughts on possible biases of the funding body. The game is won when a researcher is able to cover all three secret biases of the funding body player in a pitch.

3.1.2 Analysis

The analysis of *Pick me, please!* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.2.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Simulate/Response	Using and recognizing biases in research projects pitches	Apply (3)
Assessment, Collaboration, Communal Discovery	Researchers adapting pitches to find out secret biases, discussing ideas together	Evaluate (5)

Table 3.2: Game mechanics of *Pick me, please!* analyzed using the LM-GM model [2].

The analysis of *Pick me, please!* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. In their design document, the designers of the game specify that the purpose of the game is to learn how to pitch meaningful research projects while maintaining one's own moral beliefs and adapting to biases of those who are in power.

Content & Information. The game does not provide information about research topics or presentation styles. Only broad topics are provided as suggestions for pitches, and the pool of biases are pre-defined.

Game Mechanics. The funding body has the easier task in recognizing their own secret biases in pitches and allocating the respective colored pins to the researchers. On the other side, the researchers come up with pitches and adapt their appearance as well as presentation styles throughout rounds to narrow down possible biases, in order to finally

deduce the correct biases. The researchers can discuss their thoughts between the rounds, but do not have to.

Fiction & Narrative. The game does not provide a direct narrative other than a short description as a "deductive roleplay game with science policy". Through the game itself, it is apparent that the funding body is always biased, and specifically always has three distinctive secret biases, each regarding appearance, topic and presentation style. It is also implied that the researchers have to appeal to the funding body's preferences to receive funds for their projects.

Aesthetics & Graphics. *Pick me, please!* does not contain specific aesthetic elements or graphics in the game materials. The accessories provided for researchers to alter their appearances, e.g., sunglasses and ties, add a fun element to the game. Pitches by researcher players, their discussions about the potential secret biases the funding body holds, and how they adapt their next pitches to the knowledge gained, make up the dynamic gameplay aesthetics.

Framing. The game touches on the topics of science policy, such as project funding, project presentation, and the relationship between researchers and funding bodies. Biases that influence the success of presentations are the core element of the game. These topics are part of the Scientific Thinking and Critical Thinking lectures. Additionally, the roles of the funding body and the researchers make the relationships between them and their roles in the game's setting clear. The play literacy needed for the game is quite low, since the players are provided with a basic structure for the research pitches, and the other game content depends on the players' own creation.

Coherence and cohesiveness. While the game designers intended the purpose of the game to be learning about balancing one's beliefs and funding bodies' preferences in research pitches, I think the strength of the game lies in showing how biases of others can be difficult to pinpoint, and how deliberate attempts to appeal to biases is not as straightforward as one might assume. In addition, players practice coming up with research ideas quickly, and pitching them with different styles. These learning effects arises naturally from the gameplay, defined by the game mechanics. The narrative that funding bodies hold specific biases that the researchers have to appeal to for them to get funding sets a scene that relates to science funding policy in the real world, and is thus supported by the framing of the game given by the lecture content of DWI. Moreover, having to consciously look for biases and adapt project pitches to fit those biases lets players to experience different biases at play.

3.2 Sciendo (Scientific Thinking)

Sciendo, designed for 3-8 players, is an adaptation of the 2000 game "Zendo" by Kory Heath. It addresses the topic of Scientific Thinking by putting players in the roles of the universe and of scientists, where the universe gets to formulate a natural law that

scientists have to find out through experiments. The adaptation to a game about science was inspired by a blog post by Amanda Rosen [19], and made by Peter Purgathofer.

3.2.1 Game Description

In this game about inductive logic, one player is the universe who has to formulate a law using pyramid-shaped game pieces, and the others play as scientists that try to publish a theory about the universe that cannot be refuted. In the beginning of the game, the universe builds two examples of the law it created but keeps secret from the scientists: one example fulfills the law, the other one one does not. The scientists can ask clarifying questions, and then build their own experiments using the game pieces. The universe decides whether each scientist's experiment fulfills the law by giving each experiment an indicating marker – a white or black stone. Every time before the universe marks an experiment, scientists can decide the outcome of the experiment – either predicting its success and thus joining the experiment, or predicting its failure and not joining it. If the experiment is successful, the scientist who created the experiment gets a green publication stone. All other scientists who predicted the correct outcome of the experiment get a publication stone. Experiments stay on display with their respective white or black stone. However, they can be dismantled if the scientists run out of pyramids for new experiments.

By using a publication stone, a scientist can publish a theory about the universe. If the proposed theory is wrong, the universe has to build an experiment that refutes the theory but abides the law, and the game continues. The game ends when a scientist has published a theory that the universe cannot refute. Alternatively, if the universe has used all of the white or black stones, the game also ends in a defeat for everyone.

3.2.2 Analysis

The analysis of *Sciendo* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.3.

The analysis of *Sciendo* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. In Rosen's blog post [19], the main proposed learning objective is described as "[i]ntroduce students to fundamental methodological concepts such as hypothesis generation, data analysis, scholarly collaboration, and generalizability". In the adapted version used in DWI, it is apparent that inductive logic and scientific collaboration are the main themes addressed by the game.

Content & Information. *Sciendo* does not provide any information on the topics addressed. The textual content is limited to the game rules and examples for laws and experiments.

Game Mechanics. The scientists create experiments, learn from previous experiments and can join or vote against other experiments. At the same time, they have to manage

Game Mechanics	Implementation	Cognitive Process Dimension
Competition	Scientists predict the outcome of other scientists' experiments to earn publication stones	Apply (3)
Communal Discovery	Scientists build their knowledge based on previous experiment outcomes	Evaluate (5)
Assessment, Resource Management	Scientists have limited tries for experiments, and have to manage when to use publication stones, which can only be earned	Evaluate (5)

Table 3.3: Game mechanics of *Sciendo* analyzed using the LM-GM model [2].

the hard-earned publication stones. By using inductive reasoning, scientists may finally publish a successful theory that cannot be refuted by the universe. When playing as the universe, the player takes on a role more observant role. However, the universe also has to apply inductive logic: they formulate a law and constantly evaluate whether the experiments abide the law, and have to build experiments that refute incorrect theories.

Fiction & Narrative. In *Sciendo*, there is no clear narrative provided to the players. In its game setting, the scientists appear to be in a community where communication is unlimited, and experiments and their outcomes are shared within the science community. Only through scientific success can publication stones be earned, which are necessary to publish a theory.

Aesthetics & Graphics. The game only contains the pyramid-shaped game pieces, the black and white stones to indicate success or failure of an experiment, and the green publication stones. During gameplay, discussions and theorizing happen between scientists. Depending on the dynamic between players, the sense of a scientific community can vary between strong and weak.

Framing. *Sciendo* is a game with a strong framing around Scientific Thinking, as it addresses experimentation, inductive reasoning, and scientific community. By assuming the roles of the universe and the scientists, the players interact with each other in their respective roles and approach the tasks given to them with a specific persona in mind. There is no specific play literacy needed, as the rules are clearly defined and the steps of inductive reasoning is set in the game mechanics.

Coherence and cohesiveness. Through the game mechanics, scientist players apply inductive logic naturally, and are encouraged to engage in scientific collaboration by learning from previous experiments and actively evaluating other scientists' experiments. In the game's version of a condensed and well-connected scientific community, communi-

cation between scientists is quick and almost seamless, unlike in real life. This level of abstraction leaves out the complexity of the real-world scientific community and other relevant stakeholders around scientific discovery. However, it facilitates the scientific process in the game, which is indeed the core concept.

3.3 Robo Rumble (Computational Thinking)

Robo Rumble, designed for 2-4 players, approaches the topic of Computational Thinking by letting players create and execute algorithms for their robots on a battle field for resources and against each other. This game was created by Jörg Artaker, Pau Ros Gimeno and Max Irendorfer in "Gameful Design", summer semester 2024, and partly redesigned by the lecture team of DWI.

3.3.1 Game Description

In *Robo Rumble*, each player controls a robot on the game board, by planning the movement and action algorithms of the robot ahead of each round. Each player starts with a basic set of movement chips that can be used to plan the algorithms on their "AlgoBoard": 2 'move forward'-chips, 1 'turn left'-chip and 1 'turn right'-chip. Players can fill out their "AlgoBoard" with up to three algorithms per round named A, B, and C. These algorithms are open for everyone to see. The execution order of the algorithms, however, are secret during the planning phase and only revealed after all players have finished planning their algorithms and the execution order thereof, or after the time limit of two and a half minutes. The execution order can be any permutation of ABC (e.g., ABC, AAB, CAC). The robots execute their first planned algorithm in a row, then the second planned algorithm in the same order, and the third in the end. After all algorithms have been executed, the starting player moves on clock-wise, the collectibles on the game board are replenished, and the players get to draw additional movement chips. These can contain more advanced movements: turn 180° and diagonal movement including turning.

The grid-style game board contains obstacles and bombs, as well as collectibles like colored stones, and bonus chips for players. The colored stones are the win condition of the game – the first player to collect all 3 colored stones, that are assigned to them at the start of the game, ultimately wins the game. If a colored stone has been collected but not replenished yet, the field it left behind becomes a teleportation tile that teleports any robot that steps on it to another field. The bonus chips, which can only be collected from the game board, contain actions that can be used as actions in algorithms, once per chip:

- Bomb: places a bomb on the board that explodes upon contact, causing the robot to lose one colored stone

- Pistol: shoots in a straight line in front of the robot and hits the first robot in the line, causing it to lose one colored stone
- Bug: places a bug in another player's algorithm, causing a random step of the algorithm to be skipped
- x2: repeats the algorithm being executed
- Shield: shields the robot from the next bomb or pistol shot
- A: calls Algorithm A at this point of the algorithm as a sub-algorithm

All collectibles are only replenished after the round.

3.3.2 Analysis

The analysis of *Robo Rumble* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.4.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Competition, Capture/Elimination, Time Pressure	Competing for limited resources (collectibles) with opportunities of attack and defense, planning of algorithms under time pressure	Apply (3)
Resource Management, Assessment, Game Turns	Using and picking up collectibles, possibly collaborating with other players to achieve goals / prevent others from achieving goals	Evaluate (5)
Strategy/Planning	Planning the algorithms based on objectives and other players' previous actions	Create (6)

Table 3.4: Game mechanics of *Robo Rumble* analyzed using the LM-GM model [2].

The analysis of *Robo Rumble* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. According to the design document submitted by the game's creators, the idea behind *Robo Rumble* is to introduce core concepts of programming and algorithmic thinking to players, especially the writing of algorithms and the execution of algorithm at runtime without players' interference.

Content & Information. The game does not contain informational content about Computational Thinking or algorithms explicitly. The game pieces and collectibles are described in the instructions, and there is no further textual content.

Game Mechanics. Writing algorithms is the core of the game play. Here, players have to plan ahead and react to others' actions and plans. Through the time constraint, it might be difficult to plan one's own algorithms and react to those of the others at the same time. Additionally, the order of execution is only revealed after the planning is finished, meaning that players have to make educated guesses on opponents' plans or simply speculate. The movement set is basic in the beginning but is expanded with each round, which helps players get into the game without a lot of complexity already at the start. Similarly, bonus chips introduce complexity only later in the game. Players who get to a tile where a colored stone has been collected in the same round is transported away, which can put them in a severe disadvantage if they haven't planned for this scenario in their algorithms. When players get to execute their own algorithms at run time, interesting situations may arise, when for instance the players notice a mistake they made in the algorithm, but cannot change anything about it while it is already being executed.

Fiction & Narrative. The game is set in 2058, where the market for autonomous cleaning robots is over-saturated and the competition between companies making such robots has turned into a corporate war. The players are elite programmers that control the robots equipped with high-tech components and weapons, who want to win the corporate war for the company.

Aesthetics & Graphics. The graphics of the board and the game elements are simple and stylized, in a way that indicates the game is indeed a game and not a realistic depiction of e.g., futuristic weapons or robots. The aesthetic of the gameplay stems from players taking on the role of the programmers or even the robots themselves, and their interaction with each other in these roles.

Framing. The game addresses Computational Thinking by making writing algorithms the core game mechanic. The language used in the game to describe the game mechanics is the same as in real algorithmic contexts (e.g., function call, loop). The play literacy needed is suitable for first-year CS students, as they should already be familiar with the concepts in the game by the time they play the game. It is possibly also suitable for students of other fields of studies, since the step-wise execution of the algorithms is understandable, and the components with which the algorithms can be built are simple tiles.

Coherence and cohesiveness. The purpose of introducing core concepts of programming and algorithmic thinking is well and clearly embedded in the game mechanics. While the narrative and the aesthetics do not play a central role in the game, the game mechanics are challenging and strategically complex. Thus, the initial learning curve is quite high due to the many mechanics that influence each other. Additionally, the time constraint during the algorithm planning phase might stand in conflict with the purpose,

as the players do not have the opportunity to strategize without pressure and with a full picture of the situation (limited information about the plans of other players, and randomness introduced by game elements such as the bonus chips). Through the strong framing of the game in algorithmic thinking, the learning purposes are quite clear.

3.4 Finity! (Computational Thinking)

Finity! addresses Computational Thinking by making the concept of finite-state machines tangible through the game. This game was created by Tony Mullen and redesigned by Peter Purgathofer.

3.4.1 Game Description

The game consists of hexagonal tiles that can be put together to create a playing board depending on the number of players, and colored rings, pins and arrows, and blockers. The hexagonal tiles are valid spots for states of the finite-state machine, and have two spaces on each edge shared by two hexagonal tiles for arrows and blockers. The arrows are black or white, and stand for transitions of the finite-state machine.

In order to win, players have to build a finite-state machine using the game pieces that can create a word consisting of black and white pins, that was previously created using a random procedure. During the game, players take turns and choose from an array of actions to take that change the playing board, e.g., adding an arrow (transition), changing the direction of the arrow, moving blockers.

3.4.2 Analysis

The analysis of *Finity!* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.5.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Competition, Capture/Elimination	Blocking others' from building valid machines	Apply (3)
Game Turns, Resource Management	Using shared resources (blockers, arrows) to build the machine for oneself	Evaluate (5)

Table 3.5: Game mechanics of *Finity!* analyzed using the LM-GM model [2].

The analysis of *Finity!* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. The game's creator describes the game as an algorithmic strategy game. The purpose is evidently providing a playful approach to the topic of finite-state machines.

Content & Information. The instructions explain the concept of finite-state machines is represented through the game pieces, and does not provide more information on the topic.

Game Mechanics. Since important game pieces such as the blockers and the arrows are shared by all players and can be moved by any player, the game is dynamic and the players have to react to each others' actions constantly. In order to win the game, the players have to have a vision of how to build their own machine, and watch the actions of other players to interfere in time.

Fiction & Narrative. There is no narrative provided for the game. Players simply have the task to building a finite-state machine.

Aesthetics & Graphics. The pieces are colored for each player or in grey/black/white, they are simple and 3D-printed.

Framing. The game targets the topic of Computational Thinking directly. Even though the concept of finite-state machines is explained in short in the instructions, some basic knowledge about it is required for understanding the game. Otherwise, the game might be very overwhelming in the beginning.

Coherence and cohesiveness. The game system fits together well and reflects the purpose. When the initial learning peak is overcome, players can actively apply Computational Thinking through gameplay.

3.5 Wicked Inventions (Design Thinking)

Wicked Inventions, a game for 3-7 players, addresses the topic of Design Thinking by letting players experience a creative design process from the perspective of a customer and a team of inventors. This game was created by Tala ElMouassarani.

3.5.1 Game Description

One player is the Customer, the other players get together in groups of two or three. The Customer first draws three cards from the customer deck and chooses one – this is their identity for the rest of the game. The customer deck contains various identities, some realistic, some more fantastical, e.g., astronaut, zombie, or treasure hunter. The Inventor teams draw two philosophy cards and choose one that they have to abide by for the rest of the game. Philosophy cards are also varied in their seriousness, and contain more detailed descriptions, e.g., "You're actually a group of 100 mice in a trench coat and you're not allowed to tell anyone! However, all the products you make are tiny..."; or "Featuritis as a design philosophy? Yes! Even your simplest designs must have at least 10 functions! Can you somehow ensure that the customer is not confused?"

The Inventors start the game by creating the first prototype of a product, which follows their secret design philosophy, in 3 minutes. The prototype has to meet a list of criteria

defined in the instructions, and are then presented in one minute each team. In the mean time, the Customer has drawn three preference cards that should be considered when giving feedback to the prototype presentations, but not clearly mentioned. Possible preference cards include invisibility, festivities, hate for touchscreens, etc., and also come with a humorous text like the philosophy cards.

After listening to the Customer's feedback, the Inventor teams go back to re-design their product based on the feedback for 2 minutes, and then present again for 1 minute. This time, the designs which fit the preferences of the Customer are rewarded with a star each, and the preferences are revealed to everyone. However, the Customer utters another preference they had come up with, which now has to be included in the final product at any cost. The Inventors now have to make the adaptations to the product in 1 minute. After the final presentations, the Customer awards the creations with a star for each requirement fulfilled: (1) The team stayed true to their design philosophy; (2) The most accessible product; (3) The product most liked by the Customer; (4) The product that showed the most improvement.

In the end, the Inventor team with the most stars wins.

3.5.2 Analysis

The analysis of *Wicked Inventions* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.6.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Role-play	Customer enacting preferences; Inventors Abiding by design philosophies	Understand (2)
Feedback	Customer giving feedback; Inventors reacting to it	Analyze (4)
Collaboration	Working together as Inventor teams	Evaluate (5)
Design/Editing	Designing products as Inventors	Create (6)

Table 3.6: Game mechanics of *Wicked Inventions* analyzed using the LM-GM model [2].

The analysis of *Wicked Inventions* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. This game has the goal of teaching Design Thinking, creativity, and empathy.

Content & Information. The content of the game is presented on cards of different decks. They do not provide factual information, but instead serve as creative input or limiting factors in the game.

Game Mechanics. The customer takes on a role that defines the game, and their preferences shape the design iterations of the Inventors. The iterative design process reminds of real-life dynamics of designers and customers' back-and-forth between feasibility, clashing design visions, and customers' preferences and requirements that enter and influence the project gradually. By keeping the preferences obscure in the initial round, but the identity of the Customer being known, players have to be empathetic and creative in trying to adapting their products to the Customer.

Fiction & Narrative. The narrative of the specific games is set by the cards drawn, while the broader fictional world of the game consists of a Customer whose preferences should be respected and considered to guarantee success, and the Inventors who want to stay true to their design philosophy but also want their product to be successful by the metrics of the Customer.

Aesthetics & Graphics. The cards are simplistic – color-coded by their category and contain text that represents the content.

Framing. The game directly addresses Design Thinking, and touches on topics from the lecture, such as wicked problems, design processes and design philosophies.

Coherence and cohesiveness. The purpose of the game is reflected in the game elements, with the mechanics creating a structure for creative design processes and feedback grounds, complemented by the narrative content that provides a humorous setting. The only feature that seems curious to me is that Inventor teams which stay true to their design philosophy until the end are also rewarded a star, which does not necessarily reflect reality.

3.6 Form Follows Function (Design & Creative Thinking)

Form Follows Function, designed for 3-10 players, addresses the topics of Design Thinking and Creative Thinking by letting players discuss and guess about fictional objects' functions based on their form in an engaging way. This game was created by Kay Kender in 2023.

3.6.1 Game Description

The game is described as an AI-based variation of "Nobody is Perfect". Players take turns in being the leader of the game, who draws a card from the deck that shows an object and a question regarding the object. The images on the cards were generated by the AI tool Midjourney.

On the bottom of the card, the answer to the question is shown to the game leader, which is in turn kept secret from the other players. The game leader hides the answer, and asks the other players to write down their answer to the question from the card. The game leader also writes the correct answer on a sheet of paper, which is shuffled among

the other answers. The game leader reads out each of the answers, and all players except for the game leader put their token on the answer they think is correct.

When the true answer is revealed, points are distributed. Every player who received a token gets a point; every player who guessed correctly get two points; the game leader decides on the most original and witty (German original in the instructions: "originell") fake-answer and awards the author of it with one point; the game leader themselves do not get any points.

The player, who gets more than 27 points first, wins the game.

3.6.2 Analysis

The analysis of *Form Follows Function* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.7.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Meta-game	Create witty and/or convincing answers that get votes from other players	Analyze (4)
Design/Editing	Answering the questions, guessing the correct answers	Create (6)

Table 3.7: Game mechanics of *Form Follows Function* analyzed using the LM-GM model [2].

The analysis of *Form Follows Function* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. According to the game designer, the idea behind the game was to show that the form of design artifacts has its limits in showing or following the function, and to provide a game about how one's experiences with cultures and design concepts can influence the perception of objects.

Content & Information. There is no information on Design Thinking or Creative Thinking concepts provided by the game. The cards with images, questions and answers make up the content of the game.

Game Mechanics. The players can get points by guessing the correct answer, writing an answer that convinces other players to select the answer as the correct one, or providing an answer that gets the originality-vote from the game leader. These require the player to be creative about the objects and the answers, and be empathetic to the other players in a way that they can appeal to their way of thinking to get many votes.

Fiction & Narrative. There is no narrative provided by the game.

Aesthetics & Graphics. The cards' design is simple, and the AI-generated images vary in their style – some invoke a dystopian image of decay, some remind of steam-punk aesthetics, some seem minimalist.

Framing. The game addresses the aspect of "form follows function" from Design Thinking very directly, and provides a frame for applying Creative Thinking through gameplay. The play literacy is very low, since the mechanics are limited to guessing, writing down answers and voting on answers.

Coherence and cohesiveness. The elements of the game fit together well, and reflect the theme of showing the theory of "form follows function" in action. However, the intended purposes behind the game that question the form factor of design artifacts and point out how people with different experiences view objects differently might be too obscure to be recognized through gameplay alone.

3.7 Morality Lab (Responsible Thinking)

Morality Lab, designed for 4-6 players, deals with the topic of Responsible Thinking by providing players with scenarios that encourage them to think critically about the use of technologies and their impact on society. This game was created by Julia Hahnl, Geeske Kemper, Alina Maliha Pranzl and Theresa Reiterer in "Gameful Design", summer semester 2023.

3.7.1 Game Description

The game contains 29 scenario cards that address scenarios related to technology, e.g., a company implementing a software that predicts long-term unemployment, a school looking to buy an app against mobbing, or what to do after getting a bachelor's degree of Informatics. The scenarios come with a 5-point scale at the bottom that has two "angelic" emojis on one end and two "demonic" emojis on the other, each side also has a description, e.g., ethical to immoral, good for society to bad for society.

Players take turns in being the game leader. The game leader draws a scenario card and reads it to the group. The other players draw from the deck that contains emojis that represent the points on the 5-point scale and have to think of an answer to the scenario that fits the position of the scale they drew, for 1 minute. What cards are drawn by the players is secret to the game leader. After all players have shared their answers, the game leader has to rank their answers on the scale provided. Only if the game leader's guess of the order on the scale is correct, the players win the round. Otherwise, the round is lost and the group has to add a stone to the stone tower in the middle of the table. The game is lost if the stone tower in the middle topples over.

3.7.2 Analysis

The analysis of *Morality Lab* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.8.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Role-play	Applying oneself to the scenarios and think of answers that fit the morality assigned to the player	Understand (2)
Collaboration, Communal Discovery	Coming up with answers that fit the scale of the group	Evaluate (5)

Table 3.8: Game mechanics of *Morality Lab* analyzed using the LM-GM model [2].

The analysis of *Morality Lab* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. According to the game designers, the purpose of the game is to encourage players to think critically and question different applications of technology, and for players to learn to view topics from various standpoints.

Content & Information. The game only provides scenarios including scales, but do not elaborate on the technologies to avoid biasing players on issues.

Game Mechanics. The players position ideas of how to solve problems in technology and how to resolve conflicts in related scenarios on different scales that base on morality, societal benefit or similar factors. The ideas are then assigned positions on the scale in comparison to each other, which can create interesting discussions about what is more ethical and grant insight into players' reasoning. In order for the group to win, players have to work together to create answers to scenarios, of which the morality fits the game leader's assessment .

Fiction & Narrative. The scenario cards provide the small narrative bites that lead to discussion. On meta-game level, the players work together against the game by avoiding the situation of having to stack stones into a tower, which eventually topples over and ends the game.

Aesthetics & Graphics. The visual design of the cards is dominated by the "angelic" and "demonic" emojis, as well as a yin and yang emoji as the neutral position; the colors of the emojis are also used as background colors of the cards.

Framing. The game clearly addresses the topics of ethics and morality in the context of technology, which are part of the DWI lecture content on Responsible thinking. While the game does not require previous knowledge about the specific issues, it might be more interesting when played by people with different views on the issues who also have already

formed opinions, since this can create conflicts during discussions about the positions of arguments on the scale.

Coherence and cohesiveness. The game elements together create a system that encourages players to take on different positions on various issues, which might not fit their personal beliefs. When exposed to conflicting opinions on morality, players are enticed to critically question the positions and the topic itself. The fact that players play against the game itself, which is symbolized by the stone tower, creates a collaborative setting that creates an atmosphere fit for discussing possibly difficult questions of morality. Additionally, the game's outcomes depend on the group dynamics, and can be challenging, entertaining, frustrating, thought-provoking, or all of it.

3.8 Data, Privacy, Identity (Responsible & Policy Thinking)

Data, Privacy, Identity, designed for 2-4 players, addresses Responsible Thinking and Policy Thinking by letting players discuss about data and privacy issues from the viewpoint of different identities. The game was published by Jeannie Crowley, Ed Saber, and Kenny Graves under a Creative Commons 4.0 Attribution International License. Layout, translation and adaptation by Peter Purgathofer, with thanks to Katta Spiel.

3.8.1 Game Description

The game contains 79 data cards, 11 role cards, and a playing field. The playing field consists of 5 categories of data storage: (1) Not retrieved or stored at all, (2) Stored and only retrievable for operator and me, (3) Stored and only retrievable with my approval, (4) Stored and not accessible for me anymore, (5) Stored and compeletely public.

The players first agree on a number of data cards to use, and draw them from the shuffled deck. In the first round, the players decide together in which data storage category on the playing field to put each data card. Examples of data cards are "keystrokes and interactions on work- or school-issued computers", "facial recognition data", "childhood pictures", and "language settings on personal devices". In this round, players should discuss about their differences in opinions and think about where the concerns stem from.

In the second round, the same data cards are shuffled and to be sorted in categories again. However, this time, every player assumes the identity of the role card they randomly drew from the role cards deck for the discussion. Role cards contain identities such as "female Austrian from an immigrant background", "member of the black bloc", and "friend of someone whose name appears in an organized crime database". Players are encouraged to put emphasis on the conflicts of interest between the identities and the data instead of enforcing stereotypes and prejudices of the identities. The players now discuss the data cards as their newly assumed identities, and also discuss about why they would decide differently than before. An additional question for discussion is whether the players view

privacy from the new perspective as a right or as a privilege. There is no winning or losing in the game.

3.8.2 Analysis

The analysis of *Data, Privacy, Identity* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.9.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Role-play	identities	Understand (2)
Communal Discovery, Collaboration	Discussing about different viewpoints and differences for various identities, making decisions together	Evaluate (5)

Table 3.9: Game mechanics of *Data, Privacy, Identity* analyzed using the LM-GM model [2].

The analysis of *Data, Privacy, Identity* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. The purpose of this game is to elicit discussions about data, privacy and identity, and how these aspects influence each other.

Content & Information. The game itself does not present any information on the related topics directly to the players, and only provides the data cards, the role cards, and the playing field with the 5 categories of data storage. It assumes that the players are knowledgeable about these content to a degree that meaningful discussions about them can be held.

Game Mechanics. Discussion and coming to an agreement on data storage options is the main element of the game. The role-play aspect is less about performing the identities, but more about viewing privacy and data from the standpoint of the identities, which involves being empathetic in thinking about people of these identities' possible lived realities and struggles.

Fiction & Narrative. The narrative is created by the players themselves, and when they have assumed the roles they have drawn, by the merged version of the players and their role cards. Depending on which identities are represented in the group at the same time, the discussions can be vastly different.

Aesthetics & Graphics. The role cards are text-only, while the data cards have AI-generated pictures in addition to the text, which can influence the players' first associations with these types of data described.

Framing. *Data, Privacy, Identity* addresses various topics from DWI's lectures, such as ethical considerations, privacy, and responsibility in innovation from Responsible

Thinking, and laws, regulations and how they interact with innovation in tech from Policy Thinking. The play literacy required is very low, since the game is centered around role-play and discussions.

Coherence and cohesiveness. The game elements all complement the purpose of eliciting discussion around the relevant topics. However, conventional game elements such as win conditions, distinct goals to achieve, and evaluation of players' actions are missing. Thus, *Data, Privacy, Identity* might not be seen as a game by players, but more a tool to drive discussion. Moreover, the outcome of the game depends on the players' knowledge about the topics of the game, as well as their attitude towards discussing the topics and their readiness to assume identities that might be starkly different from their own.

3.9 Fehlschluss (Critical Thinking)

Fehlschluss, designed for 4-6 players, deals with the topic of Critical Thinking by familiarizing players with logical fallacies often encountered in discussions and public discourse. The players take turns in using and identifying various logical fallacies while debating randomly assigned topics. This game was created by Konstantin Lackner, Hannah May and Shimong Park in "Gameful Design", summer semester 2023.

3.9.1 Game Description

25 logical fallacies are represented in form of cards with the name of the fallacy, the description of it and an example quote showing how it might be used in a discussion. These contain, for example, "ad hominem", "slippery slope", and "appeal to authority".

Each player gets an equivalent deck of 5-9 fallacy cards from this card pool. A player randomly assigned as "Provocateur" first formulates an argument agreeing or disagreeing with a randomly assigned topic out of 20. The topics are sometimes light-hearted (e.g., "Dogs are the best pets!"); sometimes more philosophical in nature (e.g., "Being happy is more important than success!"); other times refer to popular culture (e.g., "The Legend of Zelda is the best computer game series!"); or are otherwise relatable topics for university students (e.g., "Distance Learning is way better than sitting in a lecture hall!"). Another player, the "Defender", then secretly chooses one of the logical fallacies from their hand cards, puts it face-down on the table, and formulates a counter-argument to the debate using this chosen fallacy. It is specified that the arguments used do not have to reflect the players' opinions, to create a low-stake environment for concentrating on the usage of logical fallacies.

While the Defender player is speaking, all other players attempt to guess which logical fallacy was used, as quickly as possible. They pick the relevant card from their own hands and place it face-down on the the fallacy card of the Defender. After the Defender is done with their argument, the card stack in front of them is flipped and the first fallacy card, that corresponds to what the Defender picked, determines the winner of the round.

This player collects all cards of this fallacy in game and keeps it in front of them on the table. This player also becomes the next Provocateur. If the logical fallacy used is not recognized by anyone, the game continues and the next clock-wise player of the Provocateur and the Defender get the respective roles. The game ends when all players only have one card left in hand. The player with the most fallacy cards collected wins.

3.9.2 Analysis

The analysis of *Fehlschluss* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.10.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Goods/Information	Name, description and example of logical fallacies	Remember (1)
Role-play	Taking position and formulating arguments that might not align with one's own beliefs	Understand (2)
Selecting/Collecting	Choosing and using logical fallacy to argue for or against the topic	Apply (3)
Competition, Time Pressure	Recognizing the logical fallacy and putting down the card before others	Apply (3)

Table 3.10: Game mechanics of *Fehlschluss* analyzed using the LM-GM model [2].

The analysis of *Fehlschluss* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. According to design documents submitted and presentations held by the game's creators, the design intention behind the game is to introduce players to logical fallacies in theory as well as practice. By using and exposing the use of such fallacies in the game, the players should also be able to recognize the fallacies after playing – in real-world debates, discussions and public discourse.

Content & Information. The game presents logical fallacies in form of cards, with the fallacies' names, simple descriptions thereof, and usage examples. This directly accessible information is also the main aspect of the game.

Game Mechanics. When acting as the Defender, the player has to apply a logical fallacy while arguing for a position they might not agree with personally. This conscious use of fallacies makes them more tangible. The other players attempt to guess the used logical fallacy before others do, which adds a competitive aspect to the game-play. Since every player has the same deck of fallacy cards in hand, they can focus on the fallacies available to them and learn to distinguish between them, without being lost to a big

pool of possibilities. Players who are more familiar with certain logical fallacies have an advantage in the game. The learning curve for players new to these fallacies is therefore significantly higher. After initial rounds, players should have gained familiarity with the fallacies. At this point, more fallacy cards can be introduced to the game to keep it exciting.

Fiction & Narrative. The Provocateur presents a topic randomly assigned to them out of a pool of 20, the ensuing game-play is then centered around this topic. While the topics are not the focus of the game, they provide a narrative frame for the fictional debates. On the one hand, the predefined topics take off the pressure of the players of having to argue for their own positions, which might be difficult to do front of people the player is not too familiar with. On the other hand, some of the questions can still spark discussions or reflection after playing, e.g., the questions about distance learning or the importance of happiness vs. success.

Aesthetics & Graphics. The fallacy cards only consist of text – first the name of the logical fallacy, then the description of it, and an example quote of how it could be used. Since *Fehlschluss* is designed for 4-6 players, remarks and discussions about the logical fallacies naturally arise. Players might debate among themselves whether a fallacy was used properly, what other fallacies might be suitable, and also have discussions about the randomly assigned topic itself. This all can lead to surprising moments that can enhance the play experience and enforce the learning effects of the game.

Framing. The game expects players to know what logical fallacies are in general, but does not require players to know them exactly or by heart. This makes it playable for the target group – students of the course DWI who have already heard about logical fallacies in the Critical Thinking part of the course or before that.

Coherence and cohesiveness. The game's content reflects the purpose of the game. Players naturally become more familiar with logical fallacies presented on the cards through playing. This is enforced through players assuming the role of the "Defender" and applying fallacies directly, or having to guess the used fallacy as quickly as possible. Recognizing the use of logical fallacies and identifying them corresponds directly to what the game designers had intended as real-world usage of what players learn from the game. Applying logical fallacies in one's own arguments, however, is not a skill designed for the players to learn. Nevertheless, it can be argued that by using fallacies in fictional debate situations can enforce the understanding of them. The time pressure in recognizing the fallacies before others in order to win does not translate to real-world scenarios, but is rather a game mechanic that adds to the excitement of the game itself. When considering the narrative of the game set by predefined topics, some topics about more serious matter could enhance the "seriousness" of the game. However, logical fallacies can be encountered not only in "serious" discussions, which in turn argues for the current mix of topics, as it seems more balanced in regard of real-world application and appearances of logical fallacies. The main aesthetic element of the game is the performance of the players themselves: how they apply logical fallacies as the "Defender", how quickly they can recognize the fallacies, and how they question and talk about the fallacies and the

topics between rounds of play. These actions are set in frame or encouraged by the game mechanics and the narrative. Any discussions that arise from play strengthen the understanding and closer examination of the logical fallacies and the broader topic of Critical Thinking.

3.10 OfficeWars (Criminal Thinking)

OfficeWars, designed for 2-4 players, deals with the topic of Criminal Thinking by using a setting where two teams of players make investment decisions in cyber attack and defense mechanisms against each other. This game was created by Sophie Prochaska, Alina Ehart and Nasim Rezaei in "Gameful Design", summer semester 2024.

3.10.1 Game Description

In this game, two teams play against each other as adverse offices. Every player has a starting capital and defense stones. Each round, players can generate money based on the cards they have laid out on the field. Money-generating cards can be depleted after certain rounds, and spots for these cards are limited. After counting the money generated, each player has to do two actions of the possible three: buy a card from the shop, play an attack card, or discard a card. The shop always contains three cards that are publicly visible to every player, these cards can be any from the deck and can be bought. Each attack destroys a corresponding defense stone, which stand for categories of cyber attacks. If the player being attacked does not have a fitting defense stone, they have to pay the attacker.

The cards contain 6 categories related to cyber security, e.g., "Network Security", "Endpoint Security", and "Data Security". These cards can be attack or defense cards. The goal of the game is to drive the opponent team into bankruptcy while balancing financial investment as well as investment in cyber attacks and defenses.

3.10.2 Analysis

The analysis of *OfficeWars* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.11.

The analysis of *OfficeWars* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. According to the game designers, OfficeWars should foster players' understanding for basic cyber security setups, the importance of cyber defense mechanisms, and the severe impact cyber attacks may have.

Content & Information. The cards contain a lot of information: The category of cyber security, the name of the method of attack or defense, a short text about an example of the attack or defense mechanic in real life, and the qualities of the card for the game.

Game Mechanics	Implementation	Cognitive Process Dimension
Capture/Elimination	Buy desired cards from the shop before the other team	Apply (3)
Competition	Defeat the opponent team with resources	Apply (3)
Resource Management	Balancing investment, attacking and defending	Evaluate (5)

Table 3.11: Game mechanics of *OfficeWars* analyzed using the LM-GM model [2].

The cards are also color-coded per category, and show a symbol that signifies whether they are an attack or a defense card.

Game Mechanics. Players follow the goal of driving the opponent into bankruptcy, which is achieved by attacking the opponent, building and thus investing in defense mechanisms, and at the same time making sure enough money is generated for further investment in attacks or defenses. Both teams compete for the same resources available in the shop.

Fiction & Narrative. The game is set in a world where two offices try to hack each other, driving the other into ruin. In this world, money is used to expand an office's available attacks and defense mechanisms, and when an office's defense is broken, it has to pay the attacking office for new attacks it suffers. Players themselves do not have a specific role, but simply work together as a team, or alone as the "office".

Aesthetics & Graphics. The game board and the cards have strong, saturated colors and are decorated with big symbols signifying danger or protection. The game pieces are simple and 3D-printed.

Framing. The game clearly addresses the topic of cyber security, and presents attack and defense mechanisms as actions in game. In DWI's Criminal Thinking chapter, (cyber) security is discussed, especially from the perspective of criminal entities such as hackers, in order to show the necessity of approaching problems related to security from various perspectives that go beyond the ones of a software engineer.

Coherence and cohesiveness. The game elements all fit the theme and the purpose of teaching cyber security concepts. Players are put in the situation of having to use cyber attacks as well as build up defenses, with an addition of a finance system. The topic of cyber security is mainly reflected in the narrative and in the content of the cards, not so much in the mechanics directly.

3.11 Cyber Siege (Criminal Thinking)

Cyber Siege addresses Criminal Thinking by familiarizing players with cyber attacks and defense strategies through card gameplay. This game was created by Paul Gerbavsits,

Edona Haziraj, Ana Vesic and Jakob Wagenitz in “Gameful Design”, summer semester 2024.

3.11.1 Game Description

In *Cyber Siege*, players collect sets of cyber attack and cyber defense cards during rounds, and can use these cards to attack other players or defend themselves against incoming attacks. The game is played in rounds, where players draw new cards and can choose to complete sets when the requirements described on the set card are met, which is having a number of matching cards that belong together conceptually. For example, the “Malware Infection” sets consists of “Malicious Link (attack)”, “File of questionable origins (attack)”, “Firewall (defense)”, and “Anti-Virus (defense)”. In addition to attack and defense cards, there are joker cards that can be used instead of any card. These joker cards have the theme of “Admin”.

In addition to completing sets, attacks can be used to target the next player. Attack cards have different effects, such as causing the target to skip the turn, or forcing the target to discard two cards and draw two new cards. An attack can be nullified through playing a defense card from the same set. A successful attack gives the attacker 1 point, a successfully defended attack gives the target 1 point. Points can also be earned through completing sets, of which the value varies depending on difficulty to complete. The game ends when a player has 16 points, or when all set cards were used. In the latter case, the player with the most points wins the game.

3.11.2 Analysis

The analysis of *Cyber Siege* using Arnab et al.’s LM-GM model [2] with Krathwohl’s revision of Bloom’s Taxonomy [11] is shown in Table 3.12.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Competition	Be ahead in points of other players	Apply (3)
Resource Management	Managing cards in hand, deciding on which cards to keep for completing sets and which to use for attacking and defending	Evaluate (5)

Table 3.12: Game mechanics of *Cyber Siege* analyzed using the LM-GM model [2].

The analysis of *Cyber Siege* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. Accoding to the game designers, *Cyber Siege* provides knowledge about how cyber attacks and defenses interact and what damage they can cause.

Content & Information. The cards consist of a title on top, a combination of emojis that serve as graphical representation of the cyber attack or defense mechanism in the middle, and a short description text of the mechanism in the bottom. In the left upper corner, a numbered code indicates which set each card belongs to. Each player also has a info card that contains the set information for easy look-up.

Game Mechanics. Players have to manage the cards in hand to win, which can be done by collecting sets, playing successful attacks, or defending incoming attacks well, or a combination of all three. This creates the dynamic that players have to make mindful decisions on which cards to use for attacking and defending, and which to keep for sets. Other players can pay attention to this information and adapt their choice in attacks and defenses accordingly.

Fiction & Narrative. The game does not provide a narrative directly. The opponent players are described as rivals in the instructions, and the players are tasked with winning over the others, but there is no back story to the game.

Aesthetics & Graphics. The cards' design evoke the image of code and cyber hacking often found in popular media, e.g., The Matrix, with red and green elements as background – red for attack cards, green for defense cards. The "Admin" joker cards are purple, and show a person wearing dark clothing including a hoodie standing in an also futuristic and cyber-like setting from behind.

Framing. The topic of Criminal Thinking is addressed by the game, with a focus on the cyber security aspect, like in *OfficeWars*. Similarly, the game presents cyber attack and defense mechanisms as actions in game.

Coherence and cohesiveness. The game elements fit the purpose of providing knowledge about cyber attacks and defenses, albeit only on a surface level, since the information presented on the cards is just a definition text that is not relevant to the gameplay. The set mechanic groups the cards together in a way that shows the relationship between different cyber security mechanisms, which can help players remember which mechanisms are connect through gameplay, since they have to use this information to complete sets. Additionally, the consequences of cyber attacks are only represented as game events affecting the targeted player, which does not show the severity of attacks, in my opinion.

3.12 The Policy Maker (Policy Thinking)

The Policy Maker, designed for 4 players, addresses the topic of Policy Thinking. The players assume the roles of Investors and a Policy Maker, pursue different goals while operating within the political and economical frame they shape together. This game was created by Shuyin Zheng and Victoria Fischer in "Gameful Design", summer semester 2023. We – the game designers and the advisors of this thesis – have published a detailed case study [25] on the game in the context of DWI winter semester 2023/24. The game's rules have been slightly adapted since then.

3.12.1 Game Description

In this game, one player acts as the Policy Maker, the others play as Investors. The goal for the Investors is to establish a monopoly in one of four business sectors present on the game board. The Policy Maker follows the opposite goal of preventing monopolies from being formed, in addition to pursuing their own, secret goal that focus on certain business sectors, all while ensuring balanced economic growth.

The game is centered around the game board, where investment progress is tracked by each Investor's game pieces and their positions on each sector's tiles. On the bottom of the board, a timeline prescribes the Policy Maker's actions. These consist of: (1) Audit: looking into Investors' hand cards; (2) Tax policy: adapt costs of investment; (3) Grant funding: distribute investment cards among Investors; (4) Holiday break: go on a break for this round and do nothings. The Investors, draw Investment cards each round and use them to invest in the different business sectors by the price set by the Policy Maker. The Investors can also fulfill Public Initiatives, which are incentives for investing a certain amount in a certain sector which rewards more investment cards if fulfilled. Additionally, Investors can engage in Market Manipulation, which uses investment cards to set back other investors' investment progress. When an Investor holds more than 20 investment cards in hand, a wealth tax is enacted and the Investor has to discard half of the hand cards.

A monopoly is created if the following situation is not resolved after one round: An Investor is at at least tile 7 of 10 in one business sector, and the next best Investor in the sector is more than 2 tiles behind. If an monopoly is established, the Investor wins. If the timeline reaches the end with no monopoly on the game board, the Policy Maker wins and can get a ranking based on their performance, which is dependent of the investment made by the Investors, whether the secret goal of the Policy Maker was fulfilled, and how many Public Initiatives were met.

3.12.2 Analysis

The analysis of *The Policy Maker* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.13.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Simulate/Response, Competition	Investors reacting to each other's actions and Policy Maker's actions; Policy Maker reacting to market development	Apply (3)
Resource Management	Investors managing investment cards	Evaluate (5)

Table 3.13: Game mechanics of *The Policy Maker* analyzed using the LM-GM model [2].

The analysis of *The Policy Maker* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. The game's mechanics were designed with the intention of letting players experience the intricate relationships between political institutions and financial actors, and the dynamics that develop out of conflicting interests.

Content & Information. The game does not contain overt information on the topics addressed. The cards only contain the titles of the card content and a short description.

Game Mechanics. The game mechanics represent an abstracted version of interaction between political and economic actors and encourage action and reaction. The imbalance in available actions and action opportunities between the Policy Maker and the Investors is intentional and should reflect the slower reaction of policies in real life, as opposed to fast-paced developments in the, e.g., technological sector. Unexperienced Policy Makers might be caught off-guard by their inability to react fast to market reactions to their own policies. Meanwhile, Investors might be caught up in their strategies of outperforming each other and in the end lose to the Policy Maker when no Investor ends up winning.

Fiction & Narrative. The narrative frame of the game is rather abstract, but tells the players that the Policy Maker is newly-elected and has a secret goal in addition to ensuring growth of the economy. The Investors are naturally put in a role that competes against each other, with the interest of establishing a monopoly. Additionally, the names of the mechanics are rooted in real-world market mechanisms and thus support the narrative of the game.

Aesthetics & Graphics. The visual elements of the game are kept simple, using colors to represent each of the four business sectors, which are found on the investment tiles on the board and in the investment cards.

Framing. Although one of the business sectors of the game is "Information Technology", the game does not directly address technological topics. It is more about the relationships between government regulation and funding, and the economy. This is addressed in DWI's Policy Thinking.

Coherence and cohesiveness. The game's purpose of showing the dynamic relationships between political and financial stakeholders through gameplay is reflected by the game elements, with a focus on the game mechanics. What players take as lessons from the game depends on the dynamics that develop during gameplay, and how decisions are made between different players.

3.13 TaleCrafters (Creative Thinking)

TaleCrafters, designed for 3-8 players, tackles Creative Thinking with providing a fast-paced setting to create new and unique stories. The game was created by Maximilian Kemmer, Felix Kerry Li and Mareike Richter in "Gameful Design", summer semester 2023.

3.13.1 Game Description

The game provides inspiration cards, 10 of each category: characters, background settings, plot-twists, objects, or moods. Each card consists of a title, which is the keyword, a fitting image and a short description text. Each round, one player is the Story (which is synonymous with Story in German – "Geschichte"), and chooses two inspiration categories and draws one card from each of the chosen categories. Within two minutes, all other players write short story beats incorporating the inspirations. The Story player then reads them out loud and chooses their favorite one to continue the story arc. The author of the chosen story beat is the Story player in the next round. The game ends after the round limit, which is initially mutually decided on by the players, with 5 being the minimum.

3.13.2 Analysis

The analysis of *TaleCrafters* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.14.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Time Pressure	Two minutes of time limit when writing	Apply (3)
Communal Discovery	Writers continue previous story beats	Evaluate (5)
Assessment	Story player chooses most fitting story beat to continue the story arc	Evaluate (5)
Design/Editing	Writing story beats based on inspiration cards chosen by the Story player	Create (6)

Table 3.14: Game mechanics of *TaleCrafters* analyzed using the LM-GM model [2].

The analysis of *TaleCrafters* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. According to the game designers, the purpose of the game is to learn to think out of the box and practice coming up with unique and original ideas. It can also be a tool for getting in a creative mood or to break writer's block.

Content & Information. There is no information in the game that directly addresses terms or concepts of Creative Thinking. The cards serve as inspirations for the upcoming story beats, and contain the keyword, an image that goes along with it, and a short text that elaborates on the keyword.

Game Mechanics. The mechanics are simple, so players can get started quickly. The game is mainly collaborative, since players write an tire story together. However, the

winner of the last round chooses the next winning story beat, so there is still a competitive aspect in the game. There are no hard criteria or requirements for the story beats to be selected, so the game's outcome depends heavily on the players individually as well as the dynamics of the group. The two minutes time limit creates pressure for players, which might contradict the freedom needed for creativity, or be the correct amount of pressure to spark creativity. The inspiration cards can, on the one hand, be limiting free-roaming ideas, but on the other hand can provide a structure that guides players' creativity.

Fiction & Narrative. The story, which is the main focus of the game, is written by the players. The inspiration cards provide inspiration, but also constraints, and the ones to apply are selected by the Story player. These cards mostly follow a fairytale/fantasy setting, for example there are "the time traveler", "the curse", "the magic forest", but there are also cards that do not have such a strong fantastical connotation, such as "the musician", "the discovery", "the feather". The images used, however, all evoke the idea of a fairytale.

Aesthetics & Graphics. The images on the inspiration cards take up 2/3 of the space, and all have a strong fairytale-connotation. The font of the cards also remind of the fantastical themes. Therefore, players are set in the role of authors of fairytale stories, which is supported by the name of the game as well as their activities.

Framing. The play literacy needed for the game is very low, as writing short story beats based on some inspiration is a simple concept. The game clearly targets the application of Creative Thinking by putting players in the roles of authors who create stories together.

Coherence and cohesiveness. All in all, the game elements complement each other in a system that encourages and facilitates creative activities in a group. However, the designers' intention of teaching to think out of the box might not fit the heavily fairytale-connotated themes of the cards that create a quite visual setting that is ought to influence the theme of the stories to be created. Further potential conflicting areas are the time pressure applied during creative output, and the inspiration cards that might be limiting creativity. At the same time, however, these factors can serve as the pressure and limitation needed to spark creativity. Additionally, this is a game of which the enjoyment as well as the outcomes heavily depends on the group of players and their interactions.

3.14 Keywords Memory (all Ways of Thinking)

Keywords Memory, designed for 2-6 players, addresses all WoTs individually with a distinct set of cards. Players have to match terms with their definition as a pair in this Memory game. The game was created by Max Ulreich, layout by Peter Purgathofer.

3.14.1 Game Description

The game is a variation on the classic Memory game, where multiple pairs of cards are first put face-down on a surface and shuffled. The players take turns in turning over two

cards of their choosing, and get to keep the cards when they are a pair. During gameplay, players keep track of the cards to find a pair successfully in their own turn. A player wins when all card pairs have been collected and this player has the most pairs in their collection.

Usually, Memory is played with pairs of identical cards, which can contain text or images. In *Keywords Memory*, the pairs are not identical – one card contains a term, or the name of a concept related to the WoT, the other contains the definition thereof. This introduces an additional challenge to the game. For example, the set for Responsible Thinking contains terms/concepts such as "Ethics of Care" and "Virtue Ethics"; the set for Creative Thinking contains "Art Bias" and "Fear of the messy unknown".

While the game is straight-forward, there are still instructions that serve as a recommendation on how to play the game, provided by the game designer: Before the game, the players should match the pairs together as a group with all cards being face-up. It is recommended to read the content of the cards out loud when a card is uncovered, and to flip both cards together. Additionally, the instructions contain a list of all terms and definitions that can be used in case the players are unsure about what is the correct matching.

3.14.2 Analysis

The analysis of *Keywords Memory* using Arnab et al.'s LM-GM model [2] with Krathwohl's revision of Bloom's Taxonomy [11] is shown in Table 3.15.

Game Mechanics	**Implementation**	**Cognitive Process Dimension**
Goods/Information	Match pairs based on their content	Remember (1)
Capture/Elimination, Competition	Get pairs discovered before others	Apply (3)
Communal Discovery, Collaboration	Discovering positions of card pairs together	Evaluate (5)

Table 3.15: Game mechanics of *Keywords Memory* analyzed using the LM-GM model [2].

The analysis of *Keywords Memory* using the SGDA Framework [15] discusses the game in regard of its game elements.

Purpose. The game's purpose is to let players get to know the terms, concepts and their definitions in a playful way.

Content & Information. The information is the most important part of this game. Each set of *Keywords Memory* covers important terms and concepts for the respective WoTs. The presentation of the information is straight-forward: on the cards and on the instructions sheet. The content is actively being processed by the players during gameplay, because it has to be constantly evaluated whether card pairs actually fit together.

Game Mechanics. The mechanics of Memory are clear and most likely already known by players. The added complexity through the not-identical pairs might cause confusion among players in the beginning, but serves to enforce the learning effects of the game by getting the players to actively think about the content instead of looking at the cards visually. The competitive but also collaborative aspects of Memory is also applied in this game, where players have to pay attention to what is happening in front of them as others play, and can compete against each other while also having the option to help each other make discoveries crucial to winning the game.

Fiction & Narrative. There is no plot or narrative in this game. The game introduces itself in the instructions as a "double memory game".

Aesthetics & Graphics. The graphical elements of the game are very simplistic: terms of names of concepts are in a bold font, definitions are in a regular font.

Framing. The game clearly targets each WoT by presenting their terms and concepts directly. The play literacy is very low, since Memory is a game widely known in Austria, and even if it was unfamiliar to someone, the rules are straight-forward and can be explained by fellow players easily, even without the instructions. The instructions provide recommendations on how to play this variation of Memory that should make the initial steps of the game easier, but is not essential to the game.

Coherence and cohesiveness. The game elements are clear and simple, and they fit together to create a game system that reflects the purpose of making players familiar with the terms and concepts of a WoT.

CHAPTER 4

Surveys and Reflection Prompts

This chapter describes both surveys used for the evaluation of GBL in DWI, and the reflection prompts created for each game used in the game workshops. Figure 4.1 visualizes how the pre-workshop survey and the post-workshop survey are structured.

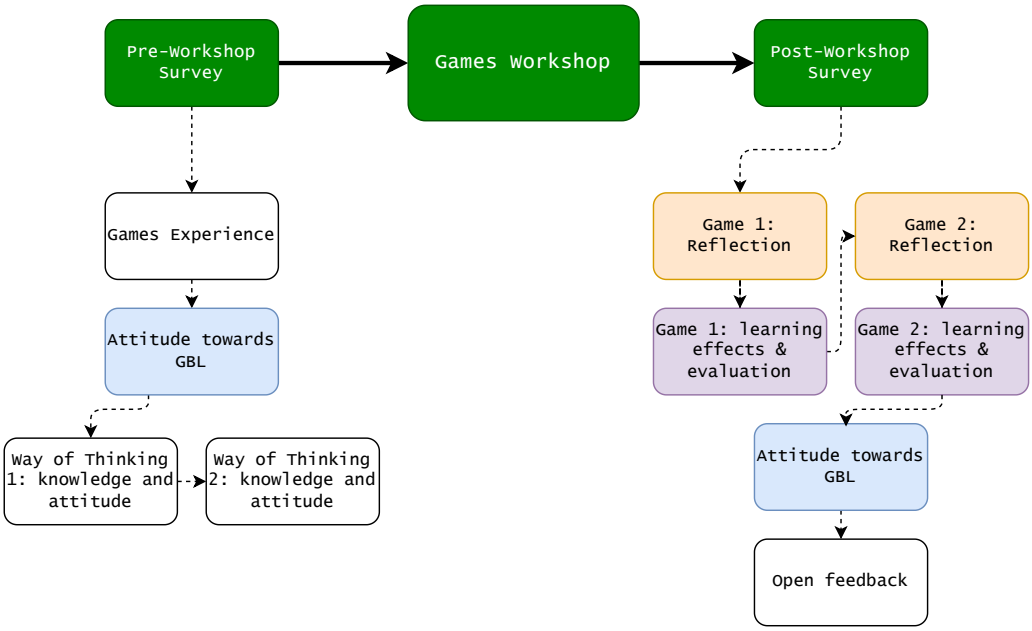

Figure 4.1: Structure of surveys and workshops, including integrated reflections

4.1 Pre-Workshop Survey

In the beginning of the pre-workshop survey, an informed consent form is provided to the students. An overview of the content of the pre- and post-workshop surveys is given, and it is made clear that while the students have to fill out both surveys (which includes writing texts based on the reflection prompts) to get points needed for completion of the course, it is their choice whether to share the content of their survey responses, after anonymization, for further scientific usage – such as for this master's thesis. There is no repercussion if students choose to not share their responses for further use.

The first part of the pre-workshop survey contains questions for demographic data: birth year of the respondent, study program, and which semester of the program the respondent is in.

4.1.1 Games experience

On the topic of experience with games, the students are asked to respond to the following three questions on a scale of never, very rarely, rarely, sometimes, often, very often, daily:

1. How often do you play board and card games? / Wie oft spielen Sie Brett- und Kartenspiele?
2. How often do you play digital single-player games? / Wie oft spielen Sie digitale Singleplayer-Spiele?
3. How often do you play digital multi-player games? / Wie oft spielen Sie digitale Multiplayer-Spiele?

These questions ask for the self-reported gaming behaviour, which might differ from the respondents' past or preferred gaming behaviours. The questions distinguish between (1) board and card games, (2) digital single-player games, and (3) digital multi-player games so the variety of games is not lost. While each category is still broad and can be broken down into genres and sub-categories, I consider the granularity enough for this thesis's purposes.

In addition to gaming frequency, the next three questions ask for familiarity with the same three categories of games on a Likert scale from 1 to 7:

4. I'm familiar with board and card games. / Ich bin vertraut mit Brett- und Kartenspielen.
5. I'm familiar with digital single-player games. / Ich bin vertraut mit digitalen Singleplayer-Spielen.
6. I'm familiar with digital multi-player games. / Ich bin vertraut mit digitalen Multiplayer-Spielen.

Responses to these questions are based on self-perception and thus should not be used as measured metrics. Nevertheless, they are indicative of what each respondent considers to be their individual familiarity with the game types. At the end of this block of questions, there is a open text field that respondents can use in case they want to explain their responses or share further thoughts.

4.1.2 Attitude towards Game-based Learning

The following questions ask for an answer on the same 1-7 Likert scale like before:

1. I'm familiar with serious games or games used for learning purposes. / Ich bin vertraut mit Serious Games bzw. Spielen, die zu Lernzwecken eingesetzt werden.
2. I think that the game-based learning approach makes sense. / Ich glaube, dass Game-based Learning (also Lernen durch Spielen) sinnvoll ist.
3. I think that Game-based learning makes sense at a university. / Ich glaube, dass Game-based Learning an einer Universität sinnvoll ist.

Together with responses to the previous block of questions about gaming experience, outcomes can be contextualized with students' previous experiences with and attitudes towards serious games, non-digital games, and games in general. The last two questions of this block will be asked again at the end of the post-workshop survey to show possible changes in students' evaluation of GBL. Again, an open text field for further comments is available.

4.1.3 Way of Thinking: knowledge and attitude

In the first and latest iteration of GBL in DWI, some students have reported that they did not gain much new knowledge from playing the games because they already had a solid understanding of the way of thinking beforehand. In order to see such cases, i.e., to be able to relate previous knowledge about a way of thinking to learning outcomes that will be collected in the post-workshop survey, the following questions ask for a self-assessment of one's knowledge about and attitude toward each way of thinking on a 1-7 Likert scale:

1. I find this way of thinking interesting. / Ich finde diese Denkweise interessant.
2. I have a good understanding of this way of thinking. / Ich habe ein gutes Verständnis von dieser Denkweise.
3. I know and understand terms that belong to this way of thinking. / Ich kenne und verstehe die Begriffe, die zu dieser Denkweise gehören.
4. I have a good understanding of what this way of thinking is all about. / Ich habe ein gutes Verständnis davon, worum es in dieser Denkweise geht.

5. I can apply concepts of this way of thinking. / Ich kann Konzepte dieser Denkweise anwenden.

Questions 1 and 2 are general questions, question 3 relates to the REMEMBER layer of Bloom's taxonomy [11], questions 4 relates to the UNDERSTAND layer, and question 5 to the APPLY layer. This section also ends with an open text field for further comments.

4.2 Post-Workshop Survey

After the students have played the games, they are tasked with filling out the post-workshop survey. For each game, they are asked how many minutes they have played, and are then presented with the reflection prompts specific to each game which they have to use to write their reflections. The students are instructed to use 30 minutes for each reflection, though the actual time spent is not collected or verified.

4.2.1 Learning effects & game evaluation

After the reflection part, the following questions are asked for each game respectively to elicit the students' self-perceived learning effects and their attitude towards the games and the GBL method.

1. This game has deepened my understanding of the way of thinking. / Ich finde, dass dieses Spiel mein Verst¨andnis der Denk- weise vertieft hat.

2. I gained new knowledge in terms of the way of thinking through this game. / Ich denke, dass ich durch dieses Spiel neues Wissen in Bezug auf die Denkweise gewonnen habe.

3. Through this game I have gotten to know or better understand terms that belong to this way of thinking. / Ich habe das Gefühl, dass ich durch dieses Spiel Begriffe kennengelernt habe bzw. besser verstehe, die zu dieser Denkweise gehören.

4. The game helped connect different concepts of this way of thinking. / Ich finde, dass das Spiel dabei geholfen hat, verschiedene Konzepte dieser Denkweise miteinander zu verbinden.

5. This game has expanded my understanding of what this way of thinking is about. / Ich glaube, dass dieses Spiel mein Verständnis darüber erweitert hat, um was es in dieser Denkweise geht.

6. I now better understand why this way of thinking is taught as part of the syllabus. / Ich verstehe jetzt besser, warum diese Denkweise als Teil der "Denkweisen der Informatik" unterrichtet wird.

7. This game helped me understand how to apply concepts from this way of thinking. / Ich finde, dass dieses Spiel mir geholfen hat, Konzepte dieser Denkweise anzuwenden.

The above questions relate to the ones in the pre-workshop survey, thus asking how the students have perceived their learning outcomes. When mapped to Bloom's taxonomy [11], Questions 2 and 3 relate to the REMEMBER layer, 4-6 relate to the UNDERSTAND layer, and 7 to the APPLY layer.

In addition, the students are asked to rate the game and optionally elaborate on their response in a open text field.

8. I found the game interesting. / Ich fand das Spiel interessant.
9. I found the game entertaining. / Ich fand das Spiel unterhaltsam.
10. I would recommend the game. / Ich würde das Spiel weiterempfehlen.

4.2.2 Attitude towards Game-based Learning + Open feedback

After both games with their ways of thinking respectively have been reflected upon and the learning outcomes were evaluated, the students are asked about their attitude towards GBL, after engaging with the method, with the following questions:

1. I think that the game-based learning approach makes sense. / Ich glaube, dass Game-based Learning sinnvoll ist.
2. I think that Game-based learning makes sense at a university. / Ich glaube, dass Game-based Learning an einer Universität sinnvoll ist.
3. I would recommend incorporating game-based learning into other courses. / Ich würde es empfehlen, Game-based Learning auch in anderen Lehrveranstaltungen einzusetzen.

The survey then concludes with another open text field for further comments, and a final text field asking for any remaining or general feedback on the game workshops, the surveys, or anything related to this activity.

4.3 Reflection Prompts

There are five reflection prompts for each game. The first three prompts are specific to the games, their strength as analyzed in the previous chapter, and their significant elements and connections to the WoTs. These prompts follow these patterns, with small variations depending on the details of each game:

- Connect game-specific experience to real-world situations or dynamics depicted in or related to the game: Guides students to reflect on topics addressed by the game, and anchoring the gameplay in real-world dynamics, as well as in the respective WoT.

- Describe strategy used in the game with game-specific examples: Guides students to reflect on skills used while playing the game, and recognize the games' intended learning effects. Additionally, this helps make it visible that various skills, often beyond what is explicitly taught in DWI but more on the soft-skills side, are used while playing the games, e.g., negotiation, logical reasoning, creativity.

- Describe interesting moments or game elements with game-specific examples: By giving examples, students are reminded of specific game elements or designed interactions, and reflect on them. This could lead students to put the experience into a fresh perspective and in context with the content they have engaged with.

In addition to the game-specific reflection prompts, two reflections prompts are the same for all games:

- Which elements from the game could become relevant for you as a Computer Scientist in the future? Why? (German original: *Welche Elemente aus dem Spiel könnten für Ihre Tätigkeit als Informatiker:in in Zukunft relevant sein? Warum?*): This reflection prompt serves the purpose of setting the game played in connection to future relevance. Additionally, it guides students to expand their frame of thinking, in case they do not view themselves as (future) Computer Scientists yet. This also might provoke further contemplation about the future, and what the students' want to do finishing their studies.

- (optional) What would you improve about the game? How and why? (German original: *Was würden Sie an dem Spiel verbessern? Wie und warum?*): Students are invited to share their improvement ideas for the game. Through actively thinking about how to re-design the games, students approach the topics and the games from a more mechanical angle and can thus view the WoTs from a changed perspective. The responses are also valuable for understanding what the students view as worth improving, and how they would approach the problems they had encountered.

4.3.1 Pick me, please!

1. How did you deal with the biases of the funding body in the game? Were you able to recognize the biases or adapt your project pitches to the biases? What was your strategy? (German original: *Wie sind Sie im Spiel mit den Vorlieben (Biases) des Fördergebys umgegangen? Konnten Sie die Vorlieben erkennen bzw. Ihre Projektanträge den Vorlieben anpassen? Was war Ihre Strategie dabei?*)

2.
   - Scientific Thinking: Explain whether and how you could also successfully apply strategies from the game in the real world. (German original: *Führen Sie aus, ob und wie Sie Strategien aus dem Spiel ebenso in der realen Welt erfolgreich einsetzen könnten.*)
   - Critical Thinking: What influencing biases do you think exist in the real world, in the field of research or outside of it? Please elaborate. (German original: *Welche beeinflussende Biases glauben Sie existieren in der realen Welt, im Bereich der Forschung oder auch außerhalb? Führen Sie bitte aus.*)

3. Describe interesting moments during the game or game elements (interactions between players, project proposals, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente während des Spiels (Interaktion zwischen Spielys, Projektanträge, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.2 Sciendo

After analyzing the game, the resulting reflection prompts are as follows:

1. What was your experience as the universe / a researcher? Compare your experience with the work of researchers in the real world. (German original: *Wie war Ihre Erfahrung als Universum/Forschende_r? Vergleichen Sie Ihre Erfahrung mit der Arbeit von Forschenden in der realen Welt.*)

2. Describe your strategies in the game. How did others react? Were you successful? Why / why not? (German original: *Beschreiben Sie Ihre Strategien beim Spiel. Wie haben andere darauf reagiert? Waren Sie erfolgreich damit? Warum / warum nicht?*)

3. Describe interesting moments during the game or game elements (interactions between players, theories, experiments, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktion zwischen Spielys, Theorien, Experimente, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.3 Robo Rumble

After analyzing the game, the resulting reflection prompts are as follows:

1. What was it like for you to control robots with algorithms? Compare your experience with what you yourself experienced when programming during your studies or in your free time. (German original: *Wie war es für Sie, Roboter mit Algorithmen zu steuern? Vergleichen Sie Ihre Erfahrung mit dem, was Sie selbst beim Programmieren im Studium oder in der Freizeit erlebt haben.*)

2. Describe your strategy in the game. Did you have complex or simple algorithms? Were you focussed on points or items? How did all this influence your success in the game? (German original: *Beschreiben Sie Ihre Strategie im Spiel. Hatten Sie eher komplexe oder einfache Algorithmen? Waren Sie auf Punkte oder Items fokussiert? Wie hat das alles Ihren Spielerfolg beeinflusst?*)

3. Describe interesting moments during the game or game elements (interaction between players/robots, algorithms, use of items, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktion zwischen Spielys/Robotern, Algorithmen, Einsatz von Items, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.4 Finity!

1. What was it like for you to build the finite-state machines with other players? Compare your experience with what you experience yourself when programming / modelling during your studies or in your free time. (German original: *Wie war es für Sie, die Automaten mit Mitspielys zu bauen? Vergleichen Sie Ihre Erfahrung mit dem, was Sie selbst beim Programmieren / Modellieren im Studium oder in der Freizeit erleben.*)

2. Describe your strategy in the game. Did you have complex or simple state machines? Were you focused on your machine or those of others? How did this influence your success in the game? (German original: *Beschreiben Sie Ihre Strategie im Spiel. Hatten Sie eher komplexe oder einfache Automaten? Waren Sie auf Ihren Automaten oder die der anderen fokussiert? Wie hat das Ihren Spielerfolg beeinflusst?*)

3. Describe interesting moments during the game or game elements (interaction between players, game maneuvers, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktion zwischen Spielys, Spielmaneuver, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.5 Wicked Inventions

1. What was it like for you to balance your design philosophy with customer wishes and to design the products iteratively? Compare this with design processes that you know from the real world. (German original: *Wie war es für Sie, Ihre Designphilosophie mit Kund:innenwünschen zu balancieren und die Produkte iterativ zu entwerfen? Vergleichen Sie das mit Designprozessen, die Sie aus der realen Welt kennen.*)

2. Describe your strategy in the game and that of your team. How did the other players react? Were you successful with it? Why / why not? (German original: *Beschreiben*

Sie Ihre Strategie im Spiel, und die Ihres Teams. Wie haben die Mitspielys darauf reagiert? Hatten Sie Erfolg damit? Warum / warum nicht?)

3. Describe interesting moments during the game or game elements (interactions, discussions, content of cards, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Diskussionen, Karteninhalte, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.6 Form Follows Function

1. - Design Thinking: Think of objects from your everyday life. Which objects would you add to this game? For which people would the game be easier / more difficult? (German original: *Denken Sie an Gegenstände aus Ihrem Alltag. Welche Gegenstände würden Sie zu diesem Spiel hinzufügen? Für welche Menschen wäre das Spiel dann einfacher/schwieriger?*)
   - Creative Thinking: Think of objects from your everyday life. Which objects would you add to this game? What answers could people who don't know these objects give to questions about them? (German original: *Denken Sie an Gegenstände aus Ihrem Alltag. Welche Gegenstände würden Sie zu diesem Spiel hinzufügen? Welche Antworten könnten Menschen, die diese Gegenstände nicht kennen, auf Fragen dazu geben?*)

2. Describe how you arrived at your answers in the game. Were you successful with your suggested answers? Why / why not? (German original: *Beschreiben Sie, wie Sie zu Ihren Antworten beim Spiel gekommen sind. Hatten Sie Erfolg mit Ihren Antwortvorschlägen? Warum / warum nicht?*)

3. Describe interesting moments during the game or game elements (interactions, objects, guesses, etc.) that particularly stuck with you and why. Were there guesses that were particularly convincing, even though they were not correct? (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Objekte, Antwortvorschläge, etc.), die Ihnen besonders im Kopf geblieben sind, und warum. Gab es Antworten, die besonders überzeugend waren, obwohl sie nicht korrekt waren?*)

4.3.7 Morality Lab

1. What was it like for you to find "angelic" and less "angelic" answers to the scenarios? Compare your experience with how projects or ideas are conceptualized in the real world. (German original: *Wie war es für Sie, "engelige" und weniger "engelige" Antworten zu den Szenarien zu finden? Vergleichen Sie Ihre Erfahrung mit dem, wie Projekte bzw. Ideen in der realen Welt konzipiert werden.*)

2. Describe your strategy for formulating the answers. How did you deal with the different scales and other players? Were you successful with your strategy? Why / why not? (German original: *Beschreiben Sie Ihre Strategie beim Formulieren der Antworten. Wie sind Sie mit den verschiedenen Skalen und den Mitspielys umgegangen? Waren Sie erfolgreich damit? Warum / warum nicht?*)

3. Describe interesting moments during the game or game elements (interactions, scenarios, answers, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Szenarien, Antworten, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.8 Data, Privacy, Identity

1.
   - Responsible Thinking: What was it like for you and your group to take on other identities and discuss in this way? Compare your experience with discussions about privacy that you know from the real world. (German original: *Wie war es für Sie und Ihre Gruppe, andere Identitäten anzunehmen und so zu diskutieren? Vergleichen Sie Ihre Erfahrung mit Diskussionen rund um Privatsphäre, die Sie aus der realen Welt kennen.*)
   - Policy Thinking: What was it like for you and your group to take on other identities and discuss in this way? Compare your experience with how decisions about data and privacy are made in the real world. (German original: *Wie war es für Sie und Ihre Gruppe, andere Identitäten anzunehmen und so zu diskutieren? Vergleichen Sie Ihre Erfahrung damit, wie Entscheidungen über Daten und Privatsphäre in der realen Welt getroffen werden.*)

2. Describe your approach when discussing with other players. How did you deal with the different identities? Were you able to assert your views? Why / why not? (German original: *Beschreiben Sie Ihre Vorgangsweise beim Diskutieren mit anderen Mitspielys. Wie sind Sie mit den verschiedenen Identitäten umgegangen? Konnten Sie sich mit Ihren Ansichten durchsetzen? Warum / warum nicht?*)

3. Describe interesting moments during the game or game elements (interactions, discussions, results etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Diskussionen, Ergebnisse etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.9 Fehlschluss

1. Did you find it easy to recognize logical fallacies in the game? Compare your experience with discussions that you know from everyday life. (German original:

Fiel es Ihnen im Spiel einfach, Fehlschlüsse zu erkennen? Vergleichen Sie Ihre Erfahrung mit Diskussionen, die Sie aus dem Alltag kennen.)

2. What was it like for you to consciously use logical fallacies? How was this experience in the group? Did the behavior in the group change during the game? (German original: *Wie war es für Sie, Fehlschlüsse gezielt und bewusst anzuwenden? Wie war diese Erfahrung in der Gruppe? Hat sich das Verhalten in der Gruppe während des Spiels verändert?*)

3. Describe interesting moments during the game or game elements (logical fallacies, examples, interactions, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Fehlschlüsse, Beispiele, Interaktionen, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.10 Office Wars

1. Describe your strategy in the game. How did the other players react to it? Were you successful with it? Why / why not? (German original: *Beschreiben Sie Ihre Strategie im Spiel. Wie haben die Mitspielys darauf reagiert? Hatten Sie Erfolg damit? Warum / warum nicht?*)

2. What was it like for you to balance attack and defense mechanisms in the game? Compare your gaming experience with cyber security mechanisms that you know from the real world. (German original: *Wie war es für Sie, im Spiel Angriff- und Abwehrmechanismen zu balancieren? Vergleichen Sie Ihre Spielerfahrung mit Cybersecurity-Mechanismen, die Sie aus der realen Welt kennen.*)

3. Describe interesting moments during the game or game elements (interactions, discussions, content of cards, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Diskussionen, Karteninhalte, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.11 Cyber Siege

1. Describe your strategy in the game. How did the other players react to it? Were you successful with it? Why / why not? (German original: *Beschreiben Sie Ihre Strategie im Spiel. Wie haben die Mitspielys darauf reagiert? Hatten Sie Erfolg damit? Warum / warum nicht?*)

2. What was it like for you to collect the card sets in the game? Compare your gaming experience with cyber security mechanisms that you know from the real world. (German original: *Wie war es für Sie, im Spiel die Kartensets zu sammeln?*

Vergleichen Sie Ihre Spielerfahrung mit Cybersecurity-Mechanismen, die Sie aus der realen Welt kennen.)

3. Describe interesting moments during the game or game elements (interactions, discussions, content of cards, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Diskussionen, Karteninhalte, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.12 The Policy Maker

1. Describe your strategy in the game. Were you successful with it? Explain whether and how your strategy can be implemented in the real world. (German original: *Beschreiben Sie Ihre Strategie im Spiel. Hatten Sie Erfolg damit? Führen Sie aus, ob und wie sich Ihre Strategie in der realen Welt umsetzen lässt.*)

2. Describe the relationship between the Policy Maker and Investors in the game. Were there conflicts, compromises or negotiations? Compare this with real-life policy-making processes. (German original: *Beschreiben Sie die Beziehung zwischen Regierung und Investys im Spiel. Gab es Konflikte, Kompromisse oder Verhandlungen? Vergleichen Sie dies mit Policy-Making-Prozessen aus der Realität.*)

3. Describe interesting moments during the game (interactions, discussions, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente (Interaktionen, Diskussionen, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.13 TaleCrafters

1. What was your experience of creativity under time pressure? How would the stories have turned out if you hadn't had time pressure? How does time pressure in programming change the quality of your work? (German original: *Wie war Ihre Erfahrung mit Kreativität unter Zeitdruck? Wie wären die Geschichten geworden, wenn Sie keinen Zeitdruck gehabt hätten? Wie verändert Zeitdruck beim Programmieren die Qualität Ihrer Arbeit?*)

2. Was your group satisfied with the stories that were created? What was it like to continue the stories of others? (German original: *War Ihre Gruppe zufrieden mit den Geschichten, die entstanden sind? Wie war es, die Geschichten von anderen fortzusetzen?*)

3. Describe interesting moments during the game (stories, interactions, discussions, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente während des Spiels (Geschichten, Interaktionen, Diskussionen, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

4.3.14 Keywords Memory

1. What was it like for you to play Memory with terms and definitions? Describe whether and how the game changed your understanding of the Way of Thinking. (German original: *Wie war es für Sie, Memory mit Schlüsselbegriff und Definition zu spielen? Beschreiben Sie, ob und wie das Spiel Ihr Verständnis von der Denkweise verändert hat.*)

2. Describe your strategy in the game, and your approach when memorizing terms or concepts. Which tactics work for you, which don't? (German original: *Beschreiben Sie Ihre Strategie im Spiel, und Ihre Herangehensweise, wenn Sie sich Begriffe oder Konzepte einprägen wollen. Welche Taktiken funktionieren für Sie, welche nicht?*)

3. Describe interesting moments during the game or game elements (interactions, discussions, content of cards, etc.) that particularly stuck with you and why. (German original: *Beschreiben Sie interessante Momente oder Spielelemente (Interaktionen, Diskussionen, Karteninhalte, etc.), die Ihnen besonders im Kopf geblieben sind, und warum.*)

CHAPTER 5

Survey Results

Out of 547 students who participated in the pre-workshop survey, 389 (71%) students gave their informed consent to letting their responses to be used for further research. Out of these 389 students, 377 students completed the post-workshop survey before the deadline, which was set at Friday of the week after the games workshops. These students therefore had up to 11 days to complete the post-workshop survey. Out of the 377 responses, 4 were omitted from the analysis because they either had obvious mistakes in the data, e.g., choosing the same way of thinking twice in the pre-workshop survey or responding to the same game for two different WoTs. Thus, the number of valid responses that are analyzed is 373.

5.1 Pre-Workshop

The majority of survey respondents (78%, 291) were born between the years of 2003 and 2006. The oldest respondent was born in 1973, the youngest in 2007. Figure 5.1 shows the distribution of the respondents' years of birth. 91% (339) of the respondents were first-year students, i.e., in their first or second semester of their study program.

Regarding gaming frequency, responses as presented in Figure 5.2 show that digital games are not only played more frequently than non-digital games, but also account for vastly more daily players, especially digital multi-player games. However, the number of respondents who play games less frequently than "sometimes" is almost on the same level than those who play more often. Some students reported that they used to play games more frequently, but stopped or reduced their gaming due to increased university work or a change in their social setting after moving away from home for university.

On the topic of familiarity with games in the aforementioned three categories (see Figure 5.3), an overwhelming majority of students responded that they are at least somewhat familiar with these games. Interestingly, more students are unfamiliar with digital

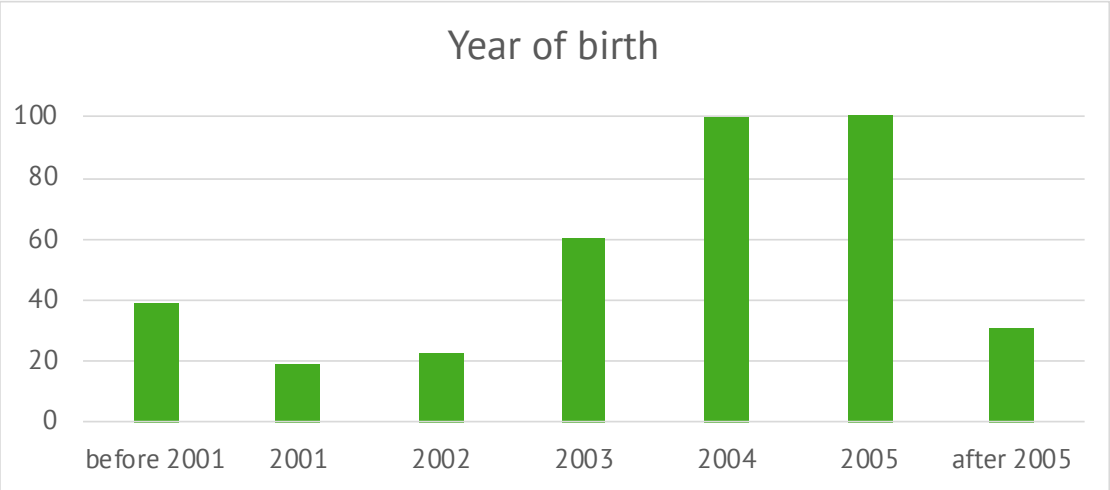

Figure 5.1: Year of birth of respondents, n=373.

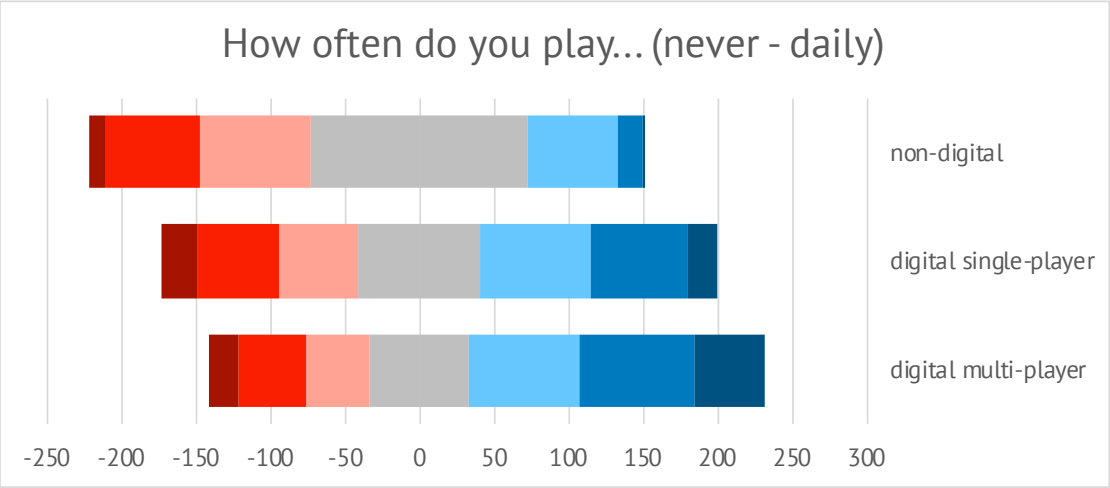

Figure 5.2: Responses to gaming frequency on a scale of never – very rarely – rarely – sometimes – often – very often – daily.

games than with non-digital games, despite the former being played more frequently. Nevertheless, more students claimed to be very familiar with digital games, as compared to non-digital games, where students would rather describe themselves as moderately familiar with it.

As shown in Figure 5.4, 47% (174) of students reported that they are not familiar with serious games or games used for learning purposes as opposed to 32% (119) who claimed they were at least somewhat familiar with such games. However, 86% (320) of students responded positively to GBL as an approach, and 75% (278) agreed that GBL makes sense at a university. Some students pointed out that the success of GBL depends on factors

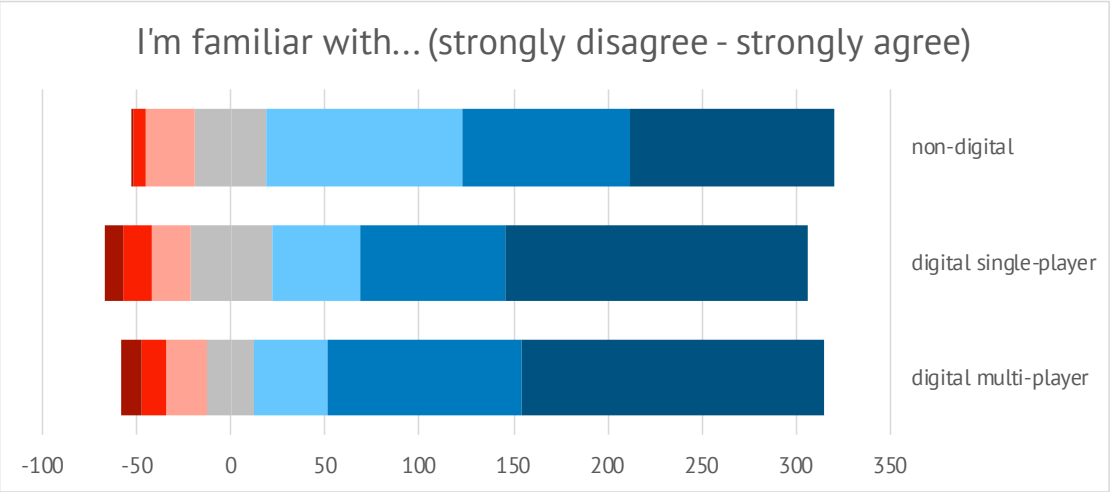

Figure 5.3: Responses to familiarity with non-digital games, digital single-player games, and digital multi-player games, on a scale of 1 (strongly disagree) to 7 (strongly agree).

such as the games' quality, the learning content, and students' willingness to engage with the material. Others expressed doubt about GBL's efficiency in teaching meaningful content, and even questioned the decision of using GBL at universities, juxtaposing playing with learning.

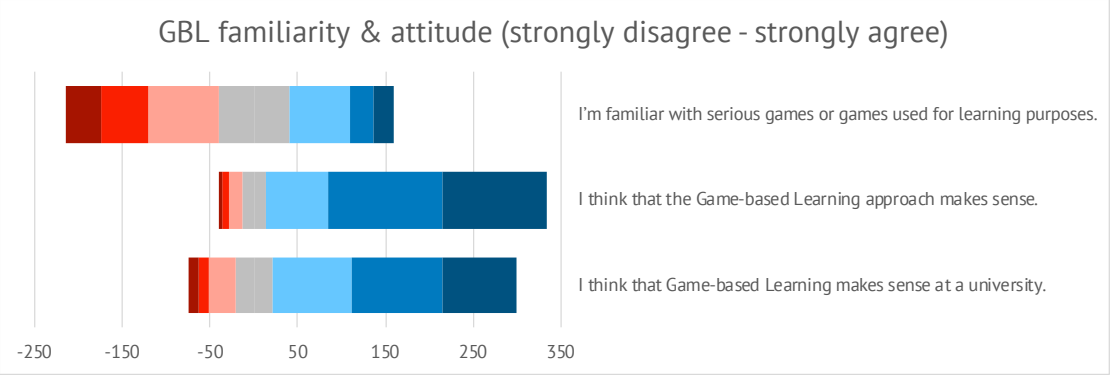

Figure 5.4: Responses to familiarity with serious games, and attitude towards GBL, on a scale of 1 (strongly disagree) to 7 (strongly agree).

Before the workshops, students were able to select two WoTs they preferred as topics for the games workshop. The number of selections for each WoT is shown in Figure 5.5, along with students' self-assessment of each WoT they plan to address in the game workshops. However, due to organizational conflicts, e.g., having the correct number of players for games, availability of games etc., some students had to play games that addressed different WoTs than those they originally selected.

Overall, students' agreement to the statements were rather positive, with interest in

Policy Thinking as the neutral outlier. Design Thinking and Critical Thinking had slightly higher medians regarding students' understanding about these WoTs. Criminal and Creative Thinking saw higher medians than other WoTs in students' interest and understanding, with the former additionally getting a higher median in knowledge and understanding of terminology than other WoTs.

	Scientific Thinking	Computational Thinking	Design Thinking	Responsible Thinking	Critical Thinking	Criminal Thinking	Policy Thinking	Creative Thinking
number of responses	135	99	80	98	77	46	116	95
I find this way of thinking interesting.	5	5	5	5	5	6	4	6
I have a good understanding of this way of thinking.	5	5	5	5	5	5	5	5
I know and understand terms that belong to this way of thinking.	5	5	5	5	5	5,5	5	5
I have a good understanding of what this way of thinking is all about.	5	5	5,5	5	6	6	5	6
I can apply concepts of this way of thinking.	5	5	5	5	5	5	5	5

Figure 5.5: Median of responses to each statement per WoT, prior to games workshops, on a scale of 1 (strongly disagree) to 7 (strongly agree).

5.2 Post-Workshop

An overview of responses to the post-workshop survey is in Figure 5.6, showing the median of responses to each statement regarding learning effects and the students' rating for the games. The games were rated quite positively. The remaining chapter discusses each game in detail together with the qualitative data.

Besides the overall median to statements, the responses are split into the following groups:

- LengthA: Responses where the length of overall reflection is less than or equal to 150 words
- LengthB: Responses where the length of overall reflection is more than 150 words
- TimeA: Responses from students who have a reported playtime of less than or equal to 30 minutes
- TimeB: Responses from students who have a reported playtime of more than 30 minutes
- If the game addresses two WoTs, the responses are also split between WoTs

	Pick me, please!	Sciendo	Robo Rumble	Finity!	Wicked Inventions	Form Follows Function	Morality Lab	Data, Privacy, Identity	Fehlschluss	OfficeWars	Cyber Siege	The Policy Maker	TaleCrafters	Keywords Memory	
number of responses	90	63	47	42	57	82	72	37	22	28	9	87	38	72	
The game has deepend my understanding of the way of thinking.	4	6	5	5	5	5	5	5	5	5	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	4	5	4	5	5	4	5	4	4,5	4	5	5	5	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	3	3	4	4	3	4	3	4	4	4	5	4	6	
The game helped connect different concepts of this way of thinking.	4	5	5	5	6	4	5	4	4	5	5	5	5	3,5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	4	6	5	5	6	4	5	5	4,5	5	4	5	6	4	
I now better understand why this way of thinking is taught as part of the syllabus.	4	6	5	5	5	5	5	5	4	5	4	5	6	4	
This game helped me understand how to apply concepts from this way of thinking.	5	6	5	5	6	5	5	5	5	5	5	5	6	3	APPLY
I found the game interesting.	5	7	5	5,5	6	6	6	5	5	6	5	6	6,5	4	
I found the game entertaining.	6	6	5	5	6	6	6	5	5	6	5	6	7	4,5	
I would recommend the game.	4	6	4	4	6	5	6	3	4	5,5	5	5	6	4	

Figure 5.6: Median of responses to each statement per game, on a scale of 1 (strongly disagree) to 7 (strongly agree).

The metric of 150 words is chosen because it amounts to an average of 30 words per reflection prompt for 5 reflection prompts, which would be around 2 sentences for each reflection prompt. While this metric does not determine the quality of reflections, I use it as an indicator for the minimum of a somewhat meaningful reflection. Similarly, I consider 30 minutes to be necessary to meaningfully engage with a game. We intended for the students to have enough time to play each game for at least 30 minutes, up to one hour. However, due to organizational difficulties, many students did not meet the playtime we had envisioned. Additionally, some students did not count the time they used for preparation, which includes reading the instructions of the games, towards the playtime.

The qualitative data is grouped into themes using Thematic Analysis following Braun and Clarke [6]. Responses that are short positive remarks without further elaboration, e.g., "this was fun", are included in the response numbers, but not in the qualitative discussion. The themes *Materials*, *Design*, *Learning*, and *Social Aspects* are not present in the responses to every game, but also not to be understood exclusively, as comments often cover multiple themes that overlap each other.

5.3 Pick me, please! (Scientific & Critical Thinking)

Figure 5.7 shows the median of responses to post-workshop survey questions for this game. From all 90 students who played *Pick me, please!*, the median responses to the questions regarding learning outcomes are mostly neutral at 4, with S3 (*Gotten to know or better understand terms*) at 3 and S7 (*Helped understand how to apply concepts*) at 5 as outliers. The game saw the highest medians in being entertaining (S9) with a 6, followed by being found interesting (S8) with a 5.

When separated by the WoT targeted by the game, the group with Scientific Thinking (n=56) agreed more with the statements regarding learning outcomes and the game-specific statements (S8-S10). The Critical Thinking group evaluated especially statements targeting the *Remember* layer (S2-S3) rather negatively. Additionally, the game received more positive responses from group LengthB (n=51) than from group LengthA, as well as from group TimeB (n=61) in comparison to TimeA.

50 of 90 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

Many students suggested improving and simplifying the instructions, writing that reading and trying to understand the instructions took a lot of time. The accessories provided were questioned by a few students for being possibly unhygienic, with cards to represent attire suggested as an alternative.

	Overall	Scientific Thinking	Critical Thinking	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	90	56	34	39	51	29	61	
The game has deepend my understanding of the way of thinking.	4	4	3,5	3	4	3	4	
I gained new knowledge in terms of the way of thinking through this game.	4	4	3	3	4	3	4	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	3	3	2,5	3	2,5	3	
The game helped connect different concepts of this way of thinking.	4	4	4	3	5	3,5	4	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	4	4	4	4	4	3,5	4	
I now better understand why this way of thinking is taught as part of the syllabus.	4	5	4	4	5	4,5	4	
This game helped me understand how to apply concepts from this way of thinking.	5	5	4	4	5	4	5	APPLY
I found the game interesting.	5	5	4,5	4	6	4	5	
I found the game entertaining.	6	6	5	5	6	5	6	
I would recommend the game.	4	4	4	3	5	4	4	

Figure 5.7: *Pick me, please!*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

Design

While some students described the game as fun in the open feedback, others criticized it as being too straight-forward and thus too easy, predictable and repetitive, once the bias system is understood. Some comments criticized the game for being too random in regard of the biases, describing some of them, especially the biases on presentation styles, as too loosely defined for players to determine whether they were properly covered by pitches. Additionally, one student remarked that the pitches ended up being similar between players, as a result of the strategy of addressing as many biases as possible. The brainstorming sessions before making pitches were described by some students as boring, and too short for coming up with meaningful or interesting pitches by others. Concrete suggestions for improvement, besides simplifying the instructions, focus on expanding the list of biases both in width (e.g., also considering project structure, team size, etc.) and depth (i.e., more variation in biases).

Learning

Four students made the remark that the game were not relevant to the WoTs besides addressing the topics of publish or perish for Scientific Thinking, and biases for Critical Thinking.

Social Aspects

One student made the comment that they personally disliked the social aspect of the game, as it relies heavily on improvisation and speaking in front of others.

5.4 Sciendo (Scientific Thinking)

As Figure 5.8 shows, the students who played *Sciendo* (n=63) responded very positively towards the statements except for S3 (*Gotten to know or better understand terms*), which has a median of 3. A median of 7 for finding the game interesting (S8) is exceptional across all games. Between the groups LengthA and LengthB as well as TimeA and TimeB, agreement with the statements increased or remained high with the latter groups, with the only exception being the median for S3 decreasing with the latter groups. This is, however, unsurprising and acceptable, since *Sciendo* does not contain informational content on Scientific Thinking but rather concentrates on application of inductive logic and the setting of a science community.

	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	63	16	47	17	46	
The game has deepend my understanding of the way of thinking.	6	5	6	5	6	
I gained new knowledge in terms of the way of thinking through this game.	5	4,5	5	5	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	4	3	4	3	
The game helped connect different concepts of this way of thinking.	5	5	5	5	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	6	5,5	6	5	6	
I now better understand why this way of thinking is taught as part of the syllabus.	6	5,5	6	5	6	
This game helped me understand how to apply concepts from this way of thinking.	6	5	6	6	6	APPLY
I found the game interesting.	7	7	7	6	7	
I found the game entertaining.	6	6	6	6	6	
I would recommend the game.	6	6	6	6	6	

Figure 5.8: *Sciendo*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

37 of 63 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

Most students commented on the instructions being too long and complicatedly written, some suggesting adding pictures for explanation or a video to explain the rules. Two students remarked on the different sizes of the pyramids being not clearly distinguishable from each other, and suggested to use different material textures for different sizes, or even introducing other shapes to the game.

Design

Some comments mentioned the pacing being slow, and that the initial complexity did not increase significantly. The role of the green publication stones was questioned, with it being described by a few students as insignificant to the game, since in their games, scientist players always had enough publication stones or were successful in publishing theories at first try. Further suggestions include allowing the universe to introduce additional laws throughout the game to increase complexity, and letting the universe win when scientists run out of stones, instead of it losing together with the scientists in this scenario.

Learning

Four students commented that since they already understood the importance of Scientific Thinking, and knew or learned a lot about this WoT before playing, they did not learn a lot from the game, but still enjoyed the activity. A few students pointed out that the game reminded them of the scientific discovery process, and described how they enjoyed the parallels to scientific research. One comment described the game's concepts of thinking and combining knowledge as a welcome change to learning about terms.

Social Aspects

While a student commented positively on players working together as team towards the common goal, another student remarked that the enjoyment from the game depends on fellow players.

5.5 Robo Rumble (Computational Thinking)

As shown in Figure 5.9, the median of overall 47 students' responses to the game is rather positive at 5, with an exception of S2 (*Gained new knowledge*) and S10 (*Would recommend the game*) being neutral at 4, and S3 (*Gotten to know or better understand terms*) being slightly negative at 3. The difference between both response length groups is small, with only S3 receiving a lower median at 2 from the LengthB group. When grouped by playtime, only 7 students are in the TimeA group, which makes the median data of this group less significant.

	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	47	22	25	7	40	
The game has deepend my understanding of the way of thinking.	5	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	4	4	4	4	4	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	3	2	2	3	
The game helped connect different concepts of this way of thinking.	5	4	5	6	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	4,5	5	3	5	
I now better understand why this way of thinking is taught as part of the syllabus.	5	5	5	5	5,5	
This game helped me understand how to apply concepts from this way of thinking.	5	5	5	6	5	APPLY
I found the game interesting.	5	5	5	5	4,5	
I found the game entertaining.	5	5	5	5	4,5	
I would recommend the game.	4	3,5	4	5	4	

Figure 5.9: *Robo Rumble*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

34 of 47 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

Many students made the suggestion to shorten and simplify the instructions, to add examples and video demonstrations. One student suggested providing the instructions online before the game workshops, so players can prepare themselves. However, some students remarked that once they understood the rules of the game, they had an entertaining experience.

Design

Three students pointed out that the start of the game was slow for them, and made various suggestions: Letting the robots start in the middle of the board instead of in corners, providing more, or even the full set of, movement tiles already in the beginning. While a few students commented on the game being too complex with too many different mechanics, others wished for more variation in items, board layout, and robot designs. Various ideas on improving the concept of algorithms in the game were shared: One student wished for a possibility to optimize the algorithms already written during the game, which directly opposes the game designers' intention of underlining how algorithms

have to be planned properly because there is no way to change it during runtime. One student suggested adding a feedback system for the algorithms' efficiency, though they have not elaborated on how to implement this idea. Two students made the suggestion of making certain parts of the algorithms permanent, which would promote idea that algorithms should be written sustainably and thus be adaptable in future.

One student mentioned that they played the game in a group of two, which is not the intended experience. This leads to the questions of whether other groups had the intended number of players and how this would have influenced the game experience. Since the surveys did not ask for the group size, these questions cannot be answered in this iteration of GBL in DWI. However, future iterations can take this aspect into account.

Learning

A student commented that they were pleasantly surprised by the quality of the game, as it was fun and "even" had some learning effect.

5.6 Finity! (Computational Thinking)

Unfortunately, the instructions for *Finity!* were incomplete at the time the workshops took place due to oversight. The part about how to define the word to produce with the finite-state machines was missing. This should be taken into consideration when evaluating the results.

As shown in Figure 5.10, the median of the 42 responses to the statements are mostly rather positive at 5, with S3 (*Gotten to know or better understand terms*) and S10 (*Would recommend the game*) being neutral exceptions at 4, and S8 (*Found the game interesting*) being a more positive exception at 5.5. When compared by reflection length and by playtime, the group with longer reflections (n=23) and the group with longer playtime (n=31) had more positive responses than their comparison groups.

25 of 42 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

Many students suggested improving and simplifying the instructions, as they needed a lot of time to get started with the game. Some students remarked on the missing part about how to determine the goal word. One student mentioned a video that helped understanding the instructions, I assume it was a video on the official YouTube channel of Finity. The 3D-printed materials and the possibility to print the materials oneself were complimented by a student.

	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	42	19	23	11	31	
The game has deepend my understanding of the way of thinking.	5	4	5	4	5	
I gained new knowledge in terms of the way of thinking through this game.	5	4	5	4	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	4	3	4	4	4	
The game helped connect different concepts of this way of thinking.	5	4	5	5	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	5	5	4	5	
I now better understand why this way of thinking is taught as part of the syllabus.	5	4	6	4	6	
This game helped me understand how to apply concepts from this way of thinking.	5	5	6	5	5	APPLY
I found the game interesting.	5,5	4	6	5	6	
I found the game entertaining.	5	4	5	4	6	
I would recommend the game.	4	4	4	3	5	

Figure 5.10: *Finity!*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

Design

A student wished for more excitement in the game, but did not elaborate on how to achieve this. Another student suggested adding constraints to the move of flipping the direction of a bridge, as they considered it to be too powerful. Two students commented that they would not recommend the game to people who are not interested or involved in Informatics, stating that they would not enjoy such a game because of its themes and complexity. The implementation of finite-state machines in the game was described as interesting by a student, but they did not consider the game itself entertaining.

Learning

One student remarked that since they already knew the concept of state machines well from another course, they did not gain a lot in terms of learning from the game. On the contrary, another student commented positively on this aspect, writing that they appreciated the learning aspect of this game, because it touched on content from other courses.

Social Aspects

One student commented that they played the game in a group of two, which was not enjoyable. Another student attributed the game's entertainment factor to the group's

dynamics, as the players were friends already, and wrote that they found the game uninteresting otherwise.

5.7 Wicked Inventions (Design Thinking)

As Figure 5.11 shows, *Wicked Inventions* received fairly positive responses of medians at 5 or 6 across all statements from 57 students, with only S3 (*Gotten to know or better understand terms*) being the neutral outlier with a median at 4. Especially statements regarding the *Understand* (S4-S6) and the *Apply* (S6) layer, as well as the statements regarding the game itself (S8-S10) received a lot of agreement. The group LengthB (n=33) showed the highest median responses to the statements, with the highest median of 7 for S9 (*Found the game entertaining*), along with the TimeB group's responses. Both B groups had the same high medians or even higher medians when compared to their respective A groups.

	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	57	24	33	23	34	
The game has deepend my understanding of the way of thinking.	5	5	6	5	5,5	
I gained new knowledge in terms of the way of thinking through this game.	5	5	5	5	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	4	4	4	4	4	
The game helped connect different concepts of this way of thinking.	6	5	6	5	6	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	6	5	6	6	6	
I now better understand why this way of thinking is taught as part of the syllabus.	5	5	6	5	5,5	
This game helped me understand how to apply concepts from this way of thinking.	6	5	6	5	6	APPLY
I found the game interesting.	6	5,5	6	5	6	
I found the game entertaining.	6	6	7	6	7	
I would recommend the game.	6	5	6	5	6	

Figure 5.11: *Wicked Inventions*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

32 of 57 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

A few students suggested improving the instructions. Among them, some remarked that an extra deck of cards with name of objects on them were not mentioned in the

instructions. Some students integrated these cards themselves, using them as inspiration for designs.

Design

One student commented that they thought the game would be even more fun if they had more time for designing and presenting. Multiple students commended the creative card content that made the experience entertaining. The design philosophies and preferences were described as sometimes simple and vague and sometimes too abstract and specific. One suggestion included adding scenarios and examples to the design philosophies, which could help players understand the concepts.

Two students suggested introducing realism to the inventions, as in that inventions should not be impossible to implement in the real world. Similarly, one student wrote that the inventions should be required to be designed to solve a specific problem, which would make different inventions more comparable. Another idea involved introducing a developer role to the team, and adding limiting parameters such as budget and deadlines to the project requirements. One student commented that they felt that the game involved too much guessing around, and wishes that the customer would be allowed to elaborate more on their wishes.

Learning

One student commented that it is difficult to learn something from the game that carries over to the real world, because to them, the game seemed to be designed for entertainment rather than education. However, other comments praised the game for fitting the topic of Design Thinking, and that it combined brainstorming and pitching ideas well. Another student, however, thought that the game is more fitting for Creative Thinking. One student remarked that while the game is good when the context of GBL is clear, they thought that otherwise players might be confused by the cards. One student wrote an elaborate praise to the game, describing that they could learn a lot from the interaction inside the team of designers and from adapting inventions to customer's wishes, and pointed out that these creative problem-solving and teamwork skills are useful also in real design and development processes.

Social Aspects

Wicked Inventions was described as a good party game and received several comments about it being entertaining. One student mentioned that the group ended up playing with the goal of creating fun ideas instead of trying to win the game.

5.8 Form Follows Function (Design & Creative Thinking)

As Figure 5.12 shows, the overall responses of 82 students is rather positive, with S8 (*Found the game interesting*) and S9 (*Found the game entertaining*) showing the highest

medians at 6. Regarding the statements about learning effects, those targeting the *Understand* (S4-S6) and the *Apply* (S6) layer received better responses than those of the *Remember* (S2-S3) layer. When compared by the WoTs addressed by the game, it received better responses by students of the Design Thinking group (n=35). Interestingly, the LengthB group (n=45) responded more negatively to S3 (*Gotten to know or better understand terms*) at 3, and S4 (*Helped connect different concepts*) at 4, than the LengthA group with shorter reflections. On the other hand, the TimeB group (n=60), in contrast to the TimeA group, rated the game better overall (S8-S10) at a median of 6, as well giving more positive responses to statements of the *Understand* layer (S4-S6), with a disagreeing response to S3 (*Gotten to know or better understand terms*) at the median of 3.

	Overall	Design Thinking	Creative Thinking	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	82	35	47	37	45	22	60	
The game has deepend my understanding of the way of thinking.	5	5	4	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	4	4	4	4	4	4	4	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	3	2	4	3	4	3	REMEMBER
The game helped connect different concepts of this way of thinking.	4	5	4	5	4	4	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	4	5	4	4	5	4	4	UNDERSTAND
I now better understand why this way of thinking is taught as part of the syllabus.	5	5	5	5	5	5	5	UNDERSTAND
This game helped me understand how to apply concepts from this way of thinking.	5	5	5	5	5	4	5	APPLY
I found the game interesting.	6	6	6	6	6	5	6	
I found the game entertaining.	6	6	6	6	6	5	6	
I would recommend the game.	5	6	5	5	5	5	6	

Figure 5.12: *Form Follows Function*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

42 of 82 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

A few students made the suggestion to simplify the instructions. Some students criticized the material used in the game, writing that due to differences in folding the paper, handwriting, pen color etc., the answers' authors could be easily identified.

Design

Many remarked that they found their small group size of 3 or 4 to be insufficient for the game to work, while others commented that in a big group of 7, the game dragged on. A few students described that they lost interest in the game with increased playtime. Several suggestions were made to balance the points gained in game and needed to win, in order to counter this problem of prolonged games. Some students described the voting process as slow, with two students suggesting that a digital and online version of the game would work better, among an idea of adding audio clips to the game. Suggestions for improving the voting system also included enforcing voting or the reveal of the votes at the same time, to avoid players influencing each other or them being able to deduce the answers based on the votes of others. Additionally, some students expressed their wish of rewarding creative answers more.

Regarding the pictures, it was remarked that some pictures were too abstract, or too easy to guess in other instances. One student especially criticized the use of AI-generated pictures, and suggested using real and existing objects. Two comments called for revealing the prompts used to generate the AI pictures, for transparency as well as for learning from the prompt-picture connection. Additionally, some students found the AI answers being too obvious, as they follow a similar pattern. Another student described their reason for a low-agreement response as them preferring working methodically instead of guessing answers like in this game.

Learning

One student from the Design Thinking group remarked that they felt that the game was better suited for Creative Thinking, although they could see how it also addressed Design Thinking. Interestingly, the Creative Thinking group had lower medians than the Design Thinking group for the game. This might indicate a different understanding of the WoTs, their concepts, and how they relate to the game.

5.9 Morality Lab (Responsible Thinking)

As shown in Figure 5.13, from 72 students who played *Morality Lab*, the responses to the statements are fairly positive, with the game-specific statements (S8-S10) being the highest medians at 6, and S3 (*Gotten to know or better understand terms*) the lowest median of 4. The game is rated especially high in the LengthB group, with S8 (*Found the game interesting*) and S9 (*Found the game entertaining*) at a median of 7. Interestingly, comparing LengthA with LengthB and TimeA with TimeB, the median for S3 decreases with the latter groups into the disagreeing range of 3 or 3.5, while the others stay the same or increase.

Since this game was also played in the last iteration of GBL in DWI, the medians to the statements can be compared. Although the statements of the *Understand* layer (S4-S6)

had higher medians in the last iteration (n=23), this year's median for S10 (*Would recommend the game*) is higher at 6.

	Previous Iteration	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	23	72	30	42	18	54	
The game has deepend my understanding of the way of thinking.	5	5	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	5	5	5	5	5	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	4	4	4	3	4	3,5	
The game helped connect different concepts of this way of thinking.	5	5	5	5,5	5	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	6	5	4	5	4,5	5	
I now better understand why this way of thinking is taught as part of the syllabus.	6	5	4	5	4	5	
This game helped me understand how to apply concepts from this way of thinking.	5	5	5	6	5	6	APPLY
I found the game interesting.	6	6	5	7	6	6	
I found the game entertaining.	6	6	5,5	7	6	6	
I would recommend the game.	5	6	5	6	6	6	

Figure 5.13: *Morality Lab*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

24 of 72 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

Unlike other games, *Morality Lab* did not receive many comments on improving the instructions. Only 3 students described the instructions as complicated or difficult to understand. More students wrote about the stones for stacking when the group makes mistakes, saying that the stones were not of an ideal shape for stacking. However, some students commented positively on the stones, as they also were used for fidgeting during the games.

Design

One student mentioned that their group consisted of only 3 people, which made the game too easy and thus not that enjoyable. Another student wrote about the similar situation of a group of 4, and suggested to introduce some additional difficulty for smaller groups. The aesthetic design of the cards was criticized by a student, who suggested using simple icons instead of emojis. Another student remarked that while they found the scales

meaningful, players used to exaggerate their positions when they drew double angels- or double demon-cards, so the game was only difficult when a more neutral position on the scale was drawn.

The cards were often described as fun. However, a student remarked that some topics, e.g., AI, were too general and would have needed sub-topics to be meaningful. Another student wondered about the goal of the game and how it fit the activity of stacking stones, while another wished for more competitiveness in the game instead of working together. These opposite views make the difference in students' personal preferences of competitiveness and collaboration visible.

Learning

One comment described the game as a good representation for Responsible Thinking. However, another student thought that the learning effects are not strong if the players do not take on positions and actively argue for them. One student felt that they did not have enough time to properly deal with a topic during a short play session.

Social Aspects

The game was often described as interesting and fun. Nevertheless, one student pointed out that the enjoyment from the game depends on the humor of the players.

5.10 Data, Privacy, Identity (Responsible & Policy Thinking)

As Figure 5.14 shows, most statements got a median of 5 from the responses (n=37), with only S3 (*Gotten to know or better understand terms*) and S10 (*Would recommend the game*) getting a slightly disagreeing median of 3, and S2 (*Gained new knowledge*) and S4 (*Helped connect different concepts*) getting a neutral median response at 4. When compared by WoT addressed by the game, the Responsible Thinking group (n=14) reported to have had a better learning and gaming experience. Furthermore, the LengthB group had more positive responses than the LengthA group, especially to the game-specific statements (S8-S10); same for the TimeB group compared to the TimeA group, although the former had a more negative response to statements targeting the *Remember* layer (S2-S3).

21 of 37 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

Two students described the instructions as unclear, one of them writing that their group adapted the game in a way that everyone's identity is kept secret, and only revealed after another guessing round at the end of the game.

	Overall	Responsible Thinking	Policy Thinking	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	37	14	23	16	21	16	21	
The game has deepend my understanding of the way of thinking.	5	5	5	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	4	4	4	4	4	4	3	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	4,5	3	4	3	3,5	3	REMEMBER
The game helped connect different concepts of this way of thinking.	4	4	4	3,5	4	4	4	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	5,5	5	5	5	5	5	UNDERSTAND
I now better understand why this way of thinking is taught as part of the syllabus.	5	5,5	5	5	5	5	5	UNDERSTAND
This game helped me understand how to apply concepts from this way of thinking.	5	5,5	5	4,5	5	5	5	APPLY
I found the game interesting.	5	4,5	5	3,5	5	4	5	
I found the game entertaining.	5	5	5	3,5	5	4	5	
I would recommend the game.	3	4,5	3	2,5	4	3	5	

Figure 5.14: *Data, Privacy, Identity*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

Design

Many comments were written on the identities of the game. One student described the identities as “too woke”, suggesting other “more interesting” identities such as a company boss who is being blackmailed or a corrupt prosecutor. Another student found discussing identities without stereotypes difficult, suggesting that in that case, the identities would just be ordinary people. Some students remarked that there were too many identities, other found some of them too specific. Others, however, suggested adding more radical identities, or combining 2-3 identity cards to introduce more complexity. Two students wished for short explanations of the identities, as they were not familiar with some of them and had to look them up. One student suggested hiding the players’ identities at first, and make others guess the identity based on how that player sorts the cards. These comments show the differences in students’ personal experiences with the topic of identities, which affects how they can relate to or empathize with various identities, and how they perceive the game and discussions stemming from it.

Two students made the observation that they spent more time discussing the categories of data storage than the identities in the group, because the categories were not clear enough to them. Another student suggested using fewer types of data, but with bigger differences, to instigate more discussions. A few comments also touched on the topic of repetitiveness after the initial rounds. Some students criticized the game for not being

competitive, as well as for a lack of tension or incentive to participate, because there was no winning or losing. One student suggested adding a system that gets everyone to contribute to the discussion, such as a reward system for interesting inputs.

Additionally, two students wrote about how their respective groups changed the game rules. One group had everyone argue for their identity, explaining why they had other consequences than the majority, which lead to everyone speaking out for their identity. The other group made a race out of the game, where whenever an option is bad for a player's identity, they can move one tile forward.

Learning

One student commented that the game is interesting for team-building, teaching discussion and joint solution-finding while playing the game. Another student from the Policy Thinking group complimented the game for fitting the WoT well.

Social Aspects

A student made the remark that the game is fun only when played with the "right" players.

5.11 Fehlschluss (Critical Thinking)

As shown in Figure 5.15, the game received neutral (4) to rather positive (5) median responses from 22 students who played it. Compared to last year's results (n=26), the medians decreased or remained at the highest score of 5. Comparing the B groups to their respective A groups, the medians increase or stay the same in B groups, with the exception of S3 (*Gotten to know or better understand terms*) between the Time groups. The highest median at 6 is shared by S7 (*Helped me understand how to apply concepts*) and S9 (*Found the game entertaining*), both in the TimeB group.

13 of 22 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

A few students complained about the instructions being too complicated or hard to understand, with one student suggesting adding an example of a game round to the start of the instructions. Two students suggested adding a list with all logical fallacies in the game to the materials.

Design

One student suggested updating the prompts for discussion, saying that some players from their group did not know specific popular culture references like the look of certain

	Previous Iteration	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	26	22	9	13	12	10	
The game has deepend my understanding of the way of thinking.	5	5	3	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	5,5	4,5	4	5	4,5	4,5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	6	4	4	4	4,5	4	REMEMBER
The game helped connect different concepts of this way of thinking.	5	4	3	4	3	4,5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	4,5	3	5	4,5	4,5	UNDERSTAND
I now better understand why this way of thinking is taught as part of the syllabus.	5	4	4	4	4	4	UNDERSTAND
This game helped me understand how to apply concepts from this way of thinking.	5	5	5	5	5	6	APPLY
I found the game interesting.	6	5	5	5	5	5	
I found the game entertaining.	6	5	5	5	5	6	
I would recommend the game.	6	4	4	5	3,5	5	

Figure 5.15: *Fehlschluss*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

Pokémons or TV shows that are part of some prompts. Another student raised a similar point, and added that the discussion prompts could be designed as cards to be drawn, to avoid getting the same numbers repeatedly through dice throws. One comment described that it was difficult to play the game since the player did not know all logical fallacies that were available. This is odd, because the game design prevents this by letting everyone use the same set of logical fallacy cards in hand, which might indicate that the writer of the comment did not play the game correctly.

A comment pointed out that the game rewards using logical fallacies that are difficult to recognize for others, which lead to debates about whether the fallacy was used correctly. Another student suggested an "advanced mode", where players have to come up with their own statements, argue for their standpoint, and defend it from other players using logical fallacies. Two students described how they changed the game rules in their respective groups. One group only had two players, so one person first used the argument and the other had to guess it. The other group had everyone choose a logical fallacy from the cards in hand, and then lead a discussion after a short thinking time, where everyone tried to use their fallacy in the discussion. The player who guessed the most correct fallacies used wins.

Social Aspects

One student wrote that they personally disliked coming up with arguments, but still had fun overall. Another student praised the game and wrote that they would play the game with their friends, and that the game dynamics depend on who you play with.

5.12 OfficeWars (Criminal Thinking)

As Figure 5.16 shows, *OfficeWars* received fairly positive responses from the 28 students who played the game. Most statements got a median of 5, with the responses to the statements targerting the *Remember* layer (S2-S3) receiving the lowest median at 4, and the game-specific statements (S8-S10) getting the highest medians of 5.5 and 6. Interestingly, the LengthB group received more negative responses to four statements (S1-S4, S9) compared to the LengthA group, and only S10 (*Would recommend the game*) received a comparably higher median at 6. Comparing the TimeB group to TimeA, no statement received a lower median.

	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	28	14	14	7	21	
The game has deepend my understanding of the way of thinking.	5	5	4,5	4	5	
I gained new knowledge in terms of the way of thinking through this game.	4	4	3	3	4	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	4	4,5	4	4	5	
The game helped connect different concepts of this way of thinking.	5	5,5	5	5	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	5	5	4	5	
I now better understand why this way of thinking is taught as part of the syllabus.	5	5	5	4	5	
This game helped me understand how to apply concepts from this way of thinking.	5	5	5	5	5	APPLY
I found the game interesting.	6	6	6	6	6	
I found the game entertaining.	6	6	5,5	5	6	
I would recommend the game.	5,5	5	6	4	6	

Figure 5.16: *OfficeWars*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

15 of 28 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

More than half of the comments were about the materials. Specifically, it was remarked that the instructions were too complicated, and that some game elements lacked explanation. It was also suggested to include an improved description of what happens in one round of play.

Design

Interestingly, a student who reported to have played the game for 55 minutes commented that the group did not have enough time to finish the game. However, the game ended for another student after 2 rounds of play. This fits the suggestions of other students for better balancing, as it was commented on a few times that the defense mechanisms in the game were too weak. Two students pointed out that it is odd that the first player to draw cards can play them immediately, leading to the frustrating situation where other players had no way to defend themselves. The mechanic of playing the card just drawn directly was also questioned by a student.

The shop keeper was described as "irrelevant to the game" by a student. Other suggestions on the economy aspect of the game include adding more cards that generate money, since it runs out fast and leaves the players with nothing to do; increasing the fund of each player; and expanding the shop to displaying five cards. In general, the shop and the actions during a player's round were commented on as areas for improvement.

Learning

Comments on the learning aspect were rather critical. One student described the game as a "standard" game with attack and defense, with its only interesting characteristic being the use of cybersecurity terms. The student then continued to write that while the game relates to the topic of cybersecurity, it does not relate to the WoT in a meaningful way. Another student commented that they did not learn much from the game because they already knew a lot about cybersecurity from their previous education, but thought that others might learn more from it.

5.13 Cyber Siege (Criminal Thinking)

As shown in Figure 5.6, *Cyber Siege* received rather positive responses to most of the statements at a median of 5, with S3 (*Gotten to know or better understand terms*), S5 (*Expanded my understanding*) and S6 (*Now better understand why this WoT is part of the syllabus*) being exceptions at a neutral median of 4. Since the game was only played by 9 students, it makes more sense to look at the qualitative data for a discussion of the results instead of splitting the quantitative data into small groups.

3 of 9 students who played this game gave feedback to improve the game or further elaborated on their responses. In order to learn more about the students' evaluation of the game, the responses to the reflection questions were also analyzed and considered.

Materials

Two students suggested simplifying the instructions, one writing that their group did not have enough time to play the game due to needing a lot of time to understand the instructions. However, one student wrote that discussing about the instructions in the group lead to an interesting discussion on card games and Criminal Thinking.

Design

Two students commented that they did not understand the game, one of them describing that some of the group rather played around with the Lego pieces. Two other students who enjoyed the game more suggested adding more point cards. One student made the remark that one card in game gave more points when discarded than when played in a full set, which confused the players. The design of the joker card as IT admins were appreciated, described as a representation of the importance of IT admins and their flexibility. One student reflected on the game design showing that putting all resources into one type of defense leaves room for other attacks. The grouping of attacks and defenses into sets spawned a discussion in one group.

On the topic of strategies used in game, one student played the cards that did not fit the purple set card immediately, which resulted in the player having many different cards cycle through the hand. The student compared this to collecting information in cybersecurity. Another student described that their strategy was waiting until the right cards appeared, like in other card games, but they were not lucky and thought that, in hindsight, they should have attacked more. Another student wrote that whenever it became apparent that a player did not have defense cards for a certain attack, others attacked that player collectively, exploiting their weakness.

Learning

One student wrote that the game showcased the scarcity of resources which made a prioritization of defense strategies necessary. Two other students reflected on their learning outcomes, writing that the game does not remind of real-world cybersecurity mechanisms, but introduces the basics of cybersecurity concepts through card descriptions.

5.14 The Policy Maker (Policy Thinking)

As Figure 5.17 shows, from all 87 students who played the game, most responses to the statements are rather positive at a median of 5, with S8 (*Found the game interesting*) and S9 (*Found the game entertaining*) being the exception at 6. Compared to last year's iteration, the median for S3 (*Gotten to know or better understand terms*) increased from

4 to 5, but S9 and S10 (*Would recommend the game*) each saw a decrease from 7 to 6 and 6 to 5 respectively.

Comparing the LengthA and the LengthB groups, most median responses are the same at 5 or 6, with a lower median of 4.5 in the former group for S3 and S6 (*Now better understand why this WoT is part of the syllabus*), and a comparably higher median in LengthA for S9 at 6.5. Between the TimeA and the TimeB groups, the median decreases from 6 to 5 for S2 (*Gained new knowledge*) but increases from 4 to 5 for S3.

	Previous Iteration	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	78	87	34	53	21	66	
The game has deepend my understanding of the way of thinking.	5	5	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	5	5	5	5	6	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	4	5	4,5	5	4	5	
The game helped connect different concepts of this way of thinking.	5	5	5	5	5	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	5	5	5	5	5	
I now better understand why this way of thinking is taught as part of the syllabus.	5	5	4,5	5	5	5	
This game helped me understand how to apply concepts from this way of thinking.	5	5	5	5	5	5	APPLY
I found the game interesting.	6	6	6	6	6	6	
I found the game entertaining.	7	6	6,5	6	6	6	
I would recommend the game.	6	5	5	5	5	5	

Figure 5.17: *The Policy Maker*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

44 of 87 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

The instructions were often described as long and complex. A few students wrote that reading and trying to make sense of the instructions lessened their enjoyment of the game. One student described the game as more complex than entertaining due to the instructions. Another student remarked that despite the long instructions, it was still unclear how some mechanics or steps are executed exactly. An idea that was raised was to have a person who knows the game at the play sessions to explain the rules. Additionally, one student suggested to separate game figures better using more different colors.

Design

The game board and cards were praised for their visually pleasing designs by a student, but also criticized for being amateurish by another. Playing as the Policy Maker or the government itself was positively commented on by one student. Another student thought that it was easy to win as the Policy Maker after playing through the game once, while two other students commented that they felt that the Policy Maker could not interfere often or quick enough to fulfill their goals, with one of the students reflecting that this might have been the goal of the game. One student was confused by the Policy Maker's goal of preventing monopolies and at the same time developing sectors to at least 8. This might be due to the student not understanding the concept of monopoly versus desired economic development in the game.

One student criticized the game for not making sense economically, because "companies" drew investment cards from different sectors, failing to realize that the players were Investors instead of distinct companies. Another misunderstanding lead to a group playing with different rules at first: they had no limit for the Public Initiatives that give card rewards, so one player quickly got ahead before others by fulfilling multiple Public Initiatives at once, which snowballed into a quick win for that player. The student commented on this situation that it showed how wealth functions as a head-start and the other Investors could not catch up at all. The student suggested to incorporate this aspect into the game, however with a limiting factor so the game is not over too quickly. In another group, 5 players were present so 2 teamed up as the Policy Maker, which lead to a fun experience as reported by a student.

Two students suggested adding discussions and negotiations to the flow of the game, to increase interaction between players and to add more strategic gameplay. Another idea included adding a bank to the game to allow Investors to have more possibilities regarding their resources. Additionally, several suggestions for balancing were made. The rewards for Public Initiatives were considered as too high by a student, the costs for Market Manipulation (setting back other players' progress) was also considered as too high by another. One student suggested raising costs generally, so a change to the taxes in the beginning does not immediately double or half the costs. In addition, one idea involved rotating the starting player of each round, since the starting player has the advantage of being able to get the Public Initiative rewards first. Adding more sectors to allow more players was also shared as an improvement idea.

Learning

One student wrote that the game did not make the essence of Policy Thinking clear for Investor players, only chances and limitations, and thus did not show who profits from policies and why. Similarly, another student commented that only the Policy Maker was using Policy Thinking actively. One Investor player described that they were focused on their strategies to win and less on the actions of the Policy Maker, therefore not learning much about Policy Thinking. Another student commented that the play session was too

short for properly dealing with a topic anyways. I would argue that while it is true that the Investors were not directly participating in policy-making, they were acting in and affected by the political frame given by the Policy Maker, which is part of what Policy Thinking is about.

Social Aspects

One student was happy about connecting with other students through playing the game. Another remarked that "maybe I enjoyed the game this much because my partners also enjoyed it".

5.15 TaleCrafters (Creative Thinking)

As shown in Figure 5.18, *TaleCrafters* received rather high median responses from 38 students who played it. Especially statements targeting the *Understand* (S4-S6) and *Apply* (S7) layers got positive responses with a median at 6, and the game-specific statements (S8-S10) received even higher medians at 6.5 for S8 (*Found the game interesting*) and 7 for S9 (*Found the game entertaining*), among 6 for S10 (*Would recommend the game*). Compared to the previous interation's responses, the medians all increased except for S1 (*Has deepened my understanding*) S10 remaining the same at 5 and 6 respectively.

Between the LengthA and the LengthB groups, the responses to statements of the *Understand* and *Apply* layers as well as the game-specific statements received even higher medians from the latter group, at 6 and 7. When compared by the time played, the TimeA group had more positive responses to the game-specific statements at 7, while the TimeB group had more positive responses to S2 (*Gained new knowledge*), S4 (*Helped connect different concepts*) and S7 (*Helped me understand how to apply concepts*).

21 of 38 students who played this game gave feedback to improve the game or further elaborated on their responses.

Design

A few students commented on the time aspect, writing that they would have liked to have more time to play, as well as more time to write in each round. One student suggested 5 minutes instead of 2 for writing, two others suggested adding a short time to think before starting to write. However, one student commented that they enjoyed writing and collaborating under time pressure. In one group, the students agreed on allowing everyone to finish writing down their ideas. Some students then filled entire post-its with story beats, which lead to more interesting, meaningful and fun stories.

One student did not like the evaluating and judging of story beats, describing it as demotivating for those players whose story beats never got picked. Another student pointed out that everyone reading their own story beats would be better for the game, because some students' handwriting might be hard to read for others, putting these players at an disadvantage.

	Previous Iteration	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	36	38	13	25	11	27	
The game has deepend my understanding of the way of thinking.	5	5	5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	4	5	5	5	4	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	3	4	4	4	4	4	
The game helped connect different concepts of this way of thinking.	4	5	5	5	4	5	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	5	6	4	6	6	6	
I now better understand why this way of thinking is taught as part of the syllabus.	4	6	5	6	6	6	
This game helped me understand how to apply concepts from this way of thinking.	5	6	5	6	5	6	APPLY
I found the game interesting.	6	6,5	6	7	7	6	
I found the game entertaining.	6	7	6	7	7	7	
I would recommend the game.	6	6	5	7	7	6	

Figure 5.18: *TaleCrafters*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

One student commented that the game lost its entertaining factor after two rounds, because it became repetitive and the stories' qualities decreased due to new elements being added constantly. Another student also wished for more story development instead of adding new elements each turn. Students pointed out that it is difficult to balance structure and limiting creative freedom, making suggestions such as connecting the end of a finished story to the beginning of the next one, only adding one new element instead of two after the initial round, and adding more abstract cards that inspire creativity, instead of some cards that were too specific (e.g., clock city, sky islands). Another idea involved having the writer of the selected story beat to also draws something on a sheet of paper, where in the end there is a joint drawing in addition to the story.

Learning

One student wrote that although they did not learn any new terms or theories, they could deepen the knowledge about Creative Thinking through playing, and that the game also works well to foster creative collaboration. Another student commented that the game helped deepen understanding their for creative processes and solution strategies in Informatics.

Social Aspects

One student was particularly happy about the game being the "ice breaker" game they had anticipated and wished for in the pre-workshop survey. Another student wrote that the game works especially well in a group with people one can already openly communicate with. In addition, one student wrote that "creative thinking games are always the most entertaining and interesting".

5.16 Keywords Memory (all Ways of Thinking)

As Figure 5.19 shows, the Keywords Memory game for all WoTs received varying responses from 72 players. The median responses to S3 (*Gotten to know or better understand terms*) is highest at 6. Other medians on the positive side are 5 for S1 (*Deepened my understanding*) and S2 (*Gained new knowledge*), and 4.5 for S9 (*Found the game entertaining*). The other statements either received a neutral median at 4, or a lower median at 3 for S7 (*Helped understand how to apply concepts*) and 3.5 for S4 (*Helped connect different concepts*).

Between the LengthA and the LengthB groups, the medians increased or remained the same with the latter group, with S4 and S9 being an exception. As for the comparison by playtime, the responses to S3 reached a median of 7 for the TimeB group compared to a 6 for the TimeA group, and the game-specific statements (S8-S10) got more positive responses in TimeB than in TimeA.

38 of 72 students who played this game gave feedback to improve the game or further elaborated on their responses.

Materials

One student remarked that a Keywords Memory set for Scientific Thinking contained a mismatching pair. For the same WoT, the definition of Epistemology had a mistake in the instruction sheet. Regarding the materials, one student suggested adding more copies of the sheet containing the terms and their definitions, so players would not have to share the single sheet.

Design

While some students criticized the game for not being entertaining at all due to it being a Memory game, some others wrote that matching pairs that are not the same was interesting. One student commented that for Computational Thinking, the game was too difficult and the group had too little time with 20 minutes. Another student suggested letting players read through the terms and definitions first and then play, to speed up the game. While a student wished for more competitive elements in the game, another student wrote that they would only recommend to play the game as a team and not against each other.

	Overall	LengthA (words <=150)	LengthB (words > 150)	TimeA (Playtime <= 30m)	TimeB (Playtime > 30m)	
number of responses	72	38	34	35	37	
The game has deepend my understanding of the way of thinking.	5	4,5	5	5	5	
I gained new knowledge in terms of the way of thinking through this game.	5	4	5,5	4	5	REMEMBER
Through this game I have gotten to know or better understand terms that belong to this way of thinking.	6	5	6,5	6	7	
The game helped connect different concepts of this way of thinking.	3,5	4	3	4	3	UNDERSTAND
This game has expanded my understanding of what this way of thinking is about.	4	4	4,5	4	4	
I now better understand why this way of thinking is taught as part of the syllabus.	4	3,5	4	4	4	
This game helped me understand how to apply concepts from this way of thinking.	3	3	3	3	3	APPLY
I found the game interesting.	4	4	4	3	4	
I found the game entertaining.	4,5	5	4	4	5	
I would recommend the game.	4	4	4	3	5	

Figure 5.19: *Keywords Memory*: Median of responses to each statement per category, on a scale of 1 (strongly disagree) to 7 (strongly agree).

Several students suggested using shorter definitions for the terms and adding more variation in sentence structure, arguing that players would otherwise remember the sentence structure rather than the definitions. Further ideas for improvement included using application of terms and examples in place of definitions, which would offer even more to consider that is related to the terms. Additional rules for a second round was suggested, with more limiting elements such as a timer. Another student had the idea of adding a level system that unlocks more advanced cards as the game goes on, to make the start to the game easier.

Learning

One student wrote that they could not learn anything with a Memory game. Another student reflected that for GBL to work, the game needs to be fun and the players need to bring willingness to learn from the game, which were not applicable to *Keywords Memory*. One comment suggested that some students would learn the text patterns to get through the game instead of actually deal with the content. On the other hand, a student commented that the game was the best possible way to make use of Memory, however, other games represented the WoTs better. Another student wrote that while the game fits the WoT, they did not see how playing it would benefit their education in Informatics.

A couple students commented that the game could not deepen the understanding of WoTs, as it only repeated what is already known about the WoTs. However, the students recognized that the game was helpful to revise the terms, and would recommend it for reinforcing content or getting an overview of topics, although it becomes too easy when players already know the terms. One student therefore pointed out that using this game in the beginning of the semester would be more meaningful than at the end of the semester.

Social Aspects

A student described that the game became fun once the group worked together and discussed about the terms and definitions.

5.17 Overall Feedback

After reflecting on and evaluating both games played, the students had a last group of statements to respond to. The first two statements tie directly back to the ones in the pre-workshop survey, showing a direct comparison of how students' attitude towards GBL changed after the workshop and the survey (Figure 5.20). Both statements saw a general shift towards more disagreement overall. For S1 (*GBL makes sense*), the number of responses with a 7 grew from 119 to 176. However, at the other end of the scale, responses with a 1 grew from 3 before the workshops to 5 after the workshops. For S2 (*GBL makes sense at a university*), the number of responses with a 7 grew from 84 to 145 after the workshops, while the responses with a 1 grew from 11 to 16.

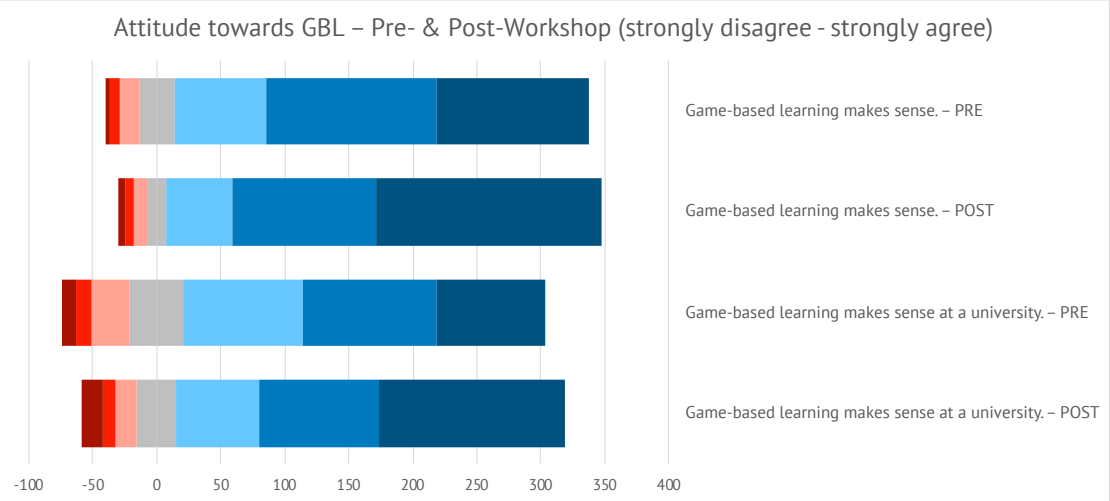

Figure 5.20: Pre- and post-workshop responses to attitude towards GBL, on a scale of 1 (strongly disagree) to 7 (strongly agree).

The third statement of the last page of the survey (*Would recommend incorporating*

GBL into other courses), together with S1 and S2, are used to indicate students' general attitude towards GBL as a method. Figure 5.21 shows the distribution of these attitudes, consisting of the rounded average of all three responses to the statements of each student. Grouped together by score, 36 students responded negatively (score of 1-3), 25 neutrally (score of 4), and 312 positively (score of 5-7). The comments provided by students to these responses, as well as their general feedback to the workshops as well as regarding GBL as a method, are discussed in the remaining subsection.

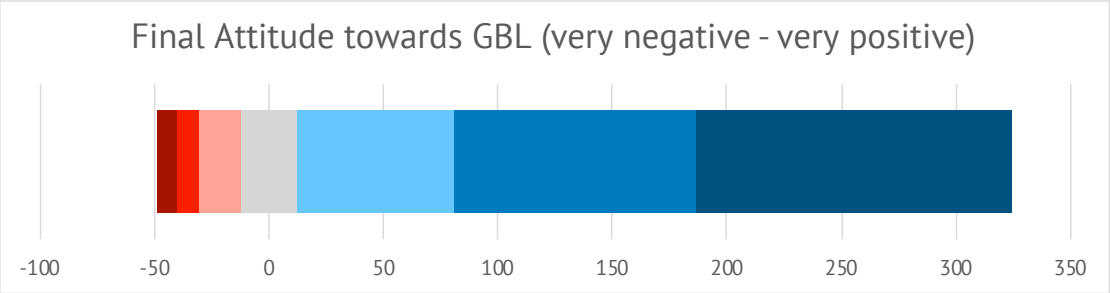

Figure 5.21: Distribution of final attitude score towards GBL, on a scale of 1 (very negative) to 7 (very positive).

Organization

Organizational issues were described, such as not having enough time to both learn the games – due to the often-times long and complex instructions – and play the games. In addition, students were not always able to build groups of the ideal size to play the games. Combined with the limited time of two hours, students often did not have enough time to finish the games or engage with them properly. The students who evaluated GBL positively in the end often wrote that they would have wanted to try out more games than two, and that they would have wanted to have more time for the games in general. However, students also showed appreciation for the workshops and the effort that went into them and the games.

The positive-GBl-attitude group also commented on the organization before the workshops and the surveys: Students had to choose the WoTs for the workshops earlier in the semester, and they did not know what to expect from the workshops or the games. This can be improved by providing more information on the workshop format as well as the games beforehand. Additionally, it was remarked that some tutors, who lead individual workshop groups, were not able to explain the games' mechanics or the meaning behind the games. This can be helped by briefing the tutors on the games before the workshops in the next iteration, which could even be combined with game sessions among tutors, also as an opportunity for them to get to know each other.

Moreover, students made suggestions for a debriefing session with other players or the tutors after playing, which could also include a guided discussion. Some students shared their experiences with each other informally, but this could be done in a more structured

and formal setting. This could be combined with another suggestion, that is letting students fill out the post-workshop survey directly after playing the games, though these would definitely require longer workshop times and more resources.

Games

In addition to the feedback students had already given in the game-specific sections, several feedback comments still pointed out how the students were unhappy or disappointed with particular games. Some reasoning that the games were not fun to motivate learning, others writing that while the games were entertaining, they did not lead to any learning. The games were also described as strongly varying in their quality, depth and time needed to play.

One student wrote that Informatics is more about critical thinking, which this is difficult to teach through games, but rather has to be taught and practiced through discussions. This student played Sciendo and Keywords Memory, which explains their comment – these two games do not contain discussions in the game flow as much as, for instance, Fehlschluss or Morality Labs. This example shows that the games played during the workshops shaped students' perception and evaluation of the activity and GBL as a method. Another students' accounts support this observation. They commented that they were not convinced of thea idea of learning through games, but changed the opinion after seeing how *The Policy Maker* executed this idea while also being entertaining. However, the student still expressed their worries about games that are designed for learning purposes put the focus on learning, which decreases the fun factor.

Surprisingly, only two students expressed the wish for using digital games instead of the non-digital games currently in use: One student suggested digital games, pointing out that digital games could provide tutorials and hints easier, that facilitate a smoother start into games; The other student compared the all-non-digital line-up of this year's game catalog to the last iteration of GBI in DWI, where students were given the option to play digital single-player games as well, which would have been preferred by this student.

Social Aspects

The positive social aspects of getting to know fellow students naturally through playing games was commented on frequently, independent of the students' enjoyment of the games themselves. Students gave positive feedback on the game workshops providing a comfortable atmosphere, where students could engage in learning in a low-pressure environment. Some students also mentioned that this opportunity to socialize with others fits the concept of DWI as course as well, describing the course as set up in a way that encourages networking among first-year students.

One student commented that they felt that games that involve elements of role-play – the example in this case being *Pick me, please!* – were not enjoyable for everyone, because of the unwillingness to "make a fool of oneself" when the other players are still stranger to the person. In the similar vein, another student wrote that they noticed the relaxed

and fun atmosphere during play was a result of the players in the group all already being familiar with each other.

On the topic of mood, one student wrote that they felt students were too stressed and busy for playing games. It was also remarked by a few students that the games workshops were set in a time period where students were preoccupied with exams in other courses, which could have had the effect of them being stressed and impatient in general. Therefore, some students questioned the timing of the workshops, suggesting shifting the workshops towards the beginning of the semester, where the games would be used to provide insight to the topics instead of deepening knowledge.

Learning and Game-based Learning

From the comments, it became apparent that students had different understandings of learning. For example, one student wrote "Knowledge is not acquired during a game, but solidified. Therefore, for a game to be effective, first there must be a basis of knowledge, that is then strengthened". Some students equated learning with gaining new factual knowledge, others linked learning to deepening knowledge and understanding. Students who reacted positively towards GBL mentioned learning more often in context with applying concepts and connecting already familiar content through games, along with soft-skills. Additionally, some students expressed that while they felt that they did not gain new knowledge about the topics, the games added to their motivation to further engage with the topics.

While many comments were positive towards the use of GBL in DWI, doubts about GBL as a method in general were expressed: Games and game workshops might become repetitive, games might be too shallow or not be able to cover complex and/or more technical topics. A few students also presented the viewpoint that GBL might be well-suited for schools, but not for universities.

GBL was compared to traditional learning methods such as reading a script or listening to lectures, and deemed possibly "too inefficient": One student wrote that the effort for learning how to play the game and playing the game were not worth the small learning effect; Another commented that while the GBL workshop itself was fun, the method would be inefficient when considering the amount of content to study in the bachelor's program; A third student wrote that they would rather have been studying for another course instead of coming to the workshop. It is curious that students evaluate their learning process and the method via efficiency, which could be explained by the pressure of academic performance. Adding to that, the already discussed stressful time period in which the game workshops took place also highlights the scarcity of students' time and energy, which might have added to their cautious evaluation of their own resources. One student wrote a particularly surprising comment, saying that they did not see why students should play games to learn things that cannot be used in the course anymore, since the semester was almost over. This view of courses and their content as separate entities that are invaluable outside of their contexts is quite disconcerting.

Among students who responded more positively towards GBL as a method, different concerns were raised. Some students felt that GBL is not taken seriously by other students, and one student in particular, who expressed their personal enjoyment of and support for GBL, worried about being stigmatized for telling fellow students that they played games at an exercise at university. They pointed out that a "correct framing" is necessary for GBL to be accepted as a method. This fits the often expressed sentiment that GBL needs willingness from the participants to have effect. However, many students are also hopeful for the future of GBL, and expressed their curiosity to further explore games for learning purposes.

5.18 Reflection & Surveys Feedback

105 of 373 students mentioned the surveys or the reflection in their feedback comments. Since the reflection prompts were integrated in the post-workshop survey, it seems that students viewed them as one entity and did not make a clear distinction between the reflection and the surveys, thus often describing the reflection prompts as survey questions in their comments. Although the task description for the GBL part of DWI as well as the informed consent text named the reflection as such, this might have been overlooked or was simply not in the students' mind. Thus, a distinction of surveys and reflection cannot be made in students' feedback, unless clearly stated.

In general, the possibility for providing feedback and sharing thoughts on the game workshops, the games, and the GBL method was appreciated. The survey questions and the reflection prompts were described as clear and understandable, with a few exceptions pointing out that they were at times repetitive and complex, and two students questioning the statements regarding learning effects, writing that they did not felt confident or comfortable in assessing their learning outcomes after a short game workshop, especially when compared to other projects done in the context of DWI and lectures, where the effort put in and the outcomes have been much greater.

The structure of the surveys were positively commented on, and most students described the length of the surveys, including the reflections, as acceptable. Several students mentioned that they liked the split format of having a pre- and a post-workshop survey, of which the pre-workshop survey helped give an overview of what was to come, and the post-workshop survey allowed them to compare their own change in attitude and opinions. A few students disliked the Likert-scale questions and were confused by the 1-7 scale. The optional text fields for elaborating on responses to the Likert-scale statements, however, were positively received.

On the reflection specifically, several students commented that they were happy about getting a structure for the reflection instead of free-writing pages of text, and positively remarked on the questions being open-ended and not-limiting at the same time. The reflection prompts were also described as meaningful guiding questions fitting to the games, and manageable in time. While one student commented that the games were "not as deep" as the questions, another wrote that although it was sometimes difficult to

answer the questions, they still lead to thinking. Additionally, one student commented that the more specific questions also lead to thinking about specific elements of the game.

Several comments mentioned being glad to revisit the experience through the reflection activity, and some students explicitly pointed out benefits of the reflection prompts:

- helped set games in context with WoT
- helped remember important WoT concepts and better understanding them
- helped reflecting on game content and discussions
- helped reflecting on one's own thinking processes
- helped reflecting on strategies, problems, interesting moments and what the games tried to say
- helped show importance of soft-skills
- helped connect terms from the course with game elements
- helped thinking about what to improve
- helped thinking about advantages of games and knowledge gained from games

The following two (translated) quotes show that the intended effects of the reflection prompts reached these students: "I really enjoyed the games workshop. The games themselves made you think about certain Ways of Thinking again. Particularly in the post-game survey, you had to establish a link between the elements of the game and the content of the Way of Thinking. In this way, we were able to recall or better understand individual important aspects of the specific Way of Thinking."; "The questions were clearly structured and allowed me to reflect on both the game and the underlying Way of Thinking. I particularly liked the questions that focused on the connection between the concepts of the Way of Thinking and the actual application in the game – this helped to better process what I had learned and develop a deeper understanding."

Still, there were a few students who remarked that they could not remember the games well enough to write meaningful reflections, and suggested communicating more clearly that the post-workshop survey should be filled out as soon as possible. Furthermore, one student wished for more questions related to GBL as a method than questions on game experience. Nevertheless, in summary, the surveys and the reflection prompts were received very positively.

CHAPTER 6

Discussion

In this chapter, the outcomes of the thesis are discussed.

6.1 Games Analysis

The games were analyzed using the LM-GM model [2] and the SGDA framework [15]. While the former was used to make the games' mechanics in detail, the latter was used to discuss the games in their elements and as a complete game system. Since the LM-GM model [2] was created with a focus on digital learning games, it was sometimes difficult to map the mechanics to non-digital game mechanics. Furthermore, the model does not elaborate on the specific game and learning mechanics, and why they are mapped on the level of thinking skills they were, which turned out to be more disorienting in the analysis than I had previously anticipated. While the SGDA framework [15] fit the goal of discussing the games better, I found that it is missing two aspects that are essential and characteristic to non-digital games but not found in single-player digital games, which make up the majority of serious games. The missing parts are: (1) social aspects, including player interactions and group dynamics, and (2) tangible aspects, as in how players interact with the game pieces, and how these interactions influence the gameplay. Passarelli et al. [17] proposed a framework for analyzing "visual and cognitive ergonomics" in board games. Although it does not address the learning aspect and is not designed for serious games specifically, it could be interesting as an addition to the digital-focused frameworks on serious games.

6.2 Surveys and Reflection Prompts

The reflection prompts resulting from the games analysis followed the pattern of (1) asking to connect game-specific experiences to real-world equivalents; (2) asking to describe in-game strategy and providing examples; (3) asking to describe interesting moments

or game elements while providing game-specific examples; (4) asking to relate game elements to a future as a Computer Scientist; (5) asking for optional feedback on the game. The idea behind the reflection prompts is to highlight relevant game elements and topics addressed by the games, so the students reflecting on these prompts can make the connections from the game to various aspects themselves, enhancing their learning effects. The reflection prompts were embedded in the post-workshop survey, which facilitated the process of students evaluating their learning effects and the games directly after writing the reflection.

However, this combined format might have lead to students not being aware that they were actively reflecting on their experiences instead of answering questions from a survey. Although the reflection part of the workshop was communicated in task descriptions, the informed consent text and in the surveys themselves, the feedback comments suggest that at least some students have missed the fact that the reflection prompts were, in fact, reflection prompts. This might explain why some students have only written very little (a few words) responding to the reflection prompts, as shown in the different answer length groups in Chapter 5 . Moreover, each reflection part was meant to take 30 minutes, which was also indicated at the top of the page with the reflection prompts. However, due to the surveys being online and unsupervised, there was no meaningful way to ensure this duration. One possible way of achieving a longer reflection time would be a minimum requirement for words written, which however could encourage usage of generative AI tools such as ChatGPT, if students, for various reasons, cannot or do not want to reach the word minimum by themselves.

Splitting the survey into a pre-workshop and a post-workshop survey had the benefit of getting data from students that is assured to be free from bias from the games workshops, and giving students a preview of what to expect afterwards. The comparison of students' attitude towards GBL before and after the workshops was valuable in showing impact of the workshops, as well as for the students themselves to consciously think about the change and reasons behind it.

The Likert-scale questions in the post-workshop survey on learning effects asked about students' self-assessment of learning effects from the games directly, which yielded rather positive results. Other approaches to getting data on this aspect would be (1) doing tests that measure students' knowledge about and understanding of terms, topics and concepts of WoTs, before and after the workshops, and compare the results; or (2) asking the same questions before and after the workshops about students' knowledge about and understanding of of WoTs instead of change, and compare the results. Approach 1 would require reliable and extensive tests that can measure the content described, approach 2 would not be able to account for learning efforts outside of the game workshops that changed students' knowledge and understanding, while still being self-reported data as the ones gathered for this thesis. Therefore, I decided to complement the Likert-scale questions with qualitative data from the responses.

The question of measuring learning outcomes is generally difficult to answer. Thus, the impact that the reflection prompts had on the students' learning effects is even more

challenging to isolate. For this reason, I chose to rely on the qualitative data from the survey responses to discuss the effect of the reflection prompts. However, it should be clarified that the responses to the reflection prompts were not analyzed, except for the game *Cyber Siege* which only had 9 players. The reason for this is the huge amount of data to analyze – 2 games per student with 5 reflection prompts each, for 373 students. Moreover, the feedback comments have provided plentiful valuable insight nonetheless.

6.3 Survey Results

The pre-workshop surveys showed that many students of DWI do not play games regularly, but most would describe themselves as being at least rather familiar with various types of games, with a slight preference for digital multi-player games. Most students described themselves as unfamiliar with serious games or games used for learning purposes, but the overall attitude towards GBL before the workshops were already overwhelmingly positive, and shifted towards more positive after the game workshops and the reflections.

6.3.1 Games

The 14 games received rather positive responses overall, both in regard of the learning effects and of the games' qualities. The top 3 games for learning, according to the amount of the high medians (6) received for the learning effect statements, are *Sciendo*, and *Wicked Invention* tied for second place with *TaleCrafters*. Using the same metric, the top 3 game in terms of being interesting, entertaining and recommendable, are *TaleCrafters*, *Sciendo*, and *Wicked Inventions* tied for third place with *Morality Lab*. However, the medians do not show the details of how the games were received, and why they were evaluated this way. Thus, the game-specific feedback suggestions were analyzed together with the responses to the Likert-scale statements.

Out of all games, only *TaleCrafters* and *Keywords Memory* did not get any negative comments on the instructions, which is understandable, since these are the games with the most straight-forward rules. The amount of complaints about the instructions might be explained by the fact that in this iteration of the games workshops, the instructions were all provided as digital PDFs behind scannable QR codes that were in the game boxes. The lack of tangibility made it impossible to flip through the instructions like it is possible with paper-format instructions, and the large page number of the files, which is explainable by the big font size used and in fact inflated by it, could have put off students. For the upcoming games workshops, the instructions should be more accessible in order to provide a quick start into the games to the players. Additionally, the improvement suggestions specific to the games' instructions in their respective sections can be considered when re-designing the instructions.

Furthermore, various improvement suggestions regarding game design were made. While many were vague and simply mentioned the areas for improvement, some students shared interesting improvement ideas or changed the rules during play, which lead to unexpected

situations that, in some cases, made the game better. Actively re-designing the games would be another way of engaging with the topic of GBL and the WoTs in DWI, especially for students who are interested in game design and GBL.

Game-specific comments also mentioned students' preferences for game characteristics, such as competitiveness versus collaborative gameplay. While personal preferences surely can influence one's perception of a game, I would argue that the design of a cohesive and coherent game system also takes into account whether the game needs to be competitive or collaborative to better reflect the purpose of the game. Additionally, social aspects impacted students' enjoyment and learning effects from the game workshops. Most students remarked about positive effects such as getting to know peers and a relaxed and fun group atmosphere elevating their experience overall. However, some students also described how they felt tension in groups or unwillingness to engage with the games, which could have negatively impacted the group's experience.

The point of using digital games instead of or alongside with non-digital games were raised a few times, mostly in connection with the benefit of digital games being better in providing tutorial elements to guide students in learning how to play the game. Nevertheless, I argue that for DWI, non-digital games have shown to be more beneficial than digital games: (1) design and production of the games are quick, and the games do not require a lot of maintenance work after production; (2) the positive social aspects that were often reported on by students can only be provided by non-digital games, since multi-player games are out of scope to implement for DWI, (3) through games workshops or game events with non-digital games, it is easier to ensure students have spent time engaging with the games than students playing digital games outside of the university.

6.3.2 Organization

The game workshops have understandably run into some organizational issues. The feedback comments often mention unsuitable group sizes and lack of time for both games. In the first iteration of GBL in DWI, students also played games in a game event setting, where many students were in a big room and could mix and match player groups for games they wanted to play more autonomously, instead of in predetermined workshop groups. While big game events introduce other organizational challenges, they still are worth considering. On the topic of time available, I agree with the students that 2 hours are too short to meaningfully engage with two games, especially taking into account the time spent on finding the correct groups and getting through the instructions.

An idea that was raised by students is adding a debriefing part to the games workshops. While this would require even more time and resources allocated to the workshops, a guided discussion on the games in groups can help students process their experience and hear about other perspectives. Furthermore, tutors who lead the game workshops can be briefed on the games beforehand, so they could help explain instructions and design intentions during the workshops. An idea would be using the games themselves as a

social event for the tutors to get acquainted with each other and as a refresher for the WoTs, at the beginning of the semester.

6.3.3 Learning and Game-based Learning

According to Vlachopoulos and Makri [22], the three main areas of learning outcomes from educational games are (1) cognitive (e.g., knowledge acquisition, perceptual skills); (2) behavioral (e.g., social skills); (3) and affective (e.g., motivation and engagement). The survey questions focused on the cognitive area of learning outcomes, but students have also commented on the behavioral and the affective areas as outcomes of the games.

While the survey questions lay out the possible learning effects in the form of statements for students to agree or disagree on, some students still gave the reason for their lack of learning outcomes as not learning any factual knowledge. In order to guide students to see learning from games from a more pluralistic view, I suggest providing an epilogue to each game that students can read through after playing the games, ideally before the reflection or as part of the reflection. The epilogue should outline the game's intended learning effects, and the game designers' thoughts behind the implementation of these learning effects and the game mechanics. This provides context around the games that can aid students in understanding their experience, and possibly also inspire them to further engage with GBL or (serious) game design. An epilogue offering context information also fits the suggestion of "clarity over stealth" from Khaled's Reflective Game Design agenda [10]. Additionally, students should also be provided with more information on what to expect from the GBL activity, so they can make more informed choices about WoTs for the games workshops and adapt their expectations for the activity.

Regarding GBL as a method specifically, some students described their observation of games being viewed more as leisure activity than a serious tool for learning. While DWI's creative and innovative approaches to teaching was appreciated by many, some students commented that they still preferred traditional teaching and learning methods. Moreover, some students criticized GBL for not being efficient enough. As already discussed in 5.17, the wish for efficiency might stem from academic pressure, and can hinder students from being open for non-conventional teaching methods or content input. According to a recent study by Zhang et al. [24], performance goals can trigger self-objectification in students, which is further linked to diminished authenticity. Therefore, I argue that it is crucial for schools and universities to implement various teaching methods to foster a pluralistic understanding of learning in students, instead of reinforcing performance goals are built on interpersonal comparison and evaluating students based on normative standards.

CHAPTER 7

Summary and Future Work

In winter semester 2024/25, the course Denkweisen der Informatik (DWI, english: Ways of Thinking in Informatics) implemented Game-based Learning (GBL) by providing 14 non-digital games to students to be played in workshops. This thesis followed the goals of (1) enhancing the GBL activity by providing reflection prompts that guide students in reflecting about their play experiences; and (2) evaluating students' responses to the games, the GBL activity, and GBL as a method, in order to distill design considerations for future games for GBL, as well as for future GBL activities.

Arnab et al.'s LM-GM model [2] and Mitgutsch and Alvarado's SGDA framework [15] were used to analyze the games and their learning purposes/effects. Since both are focused on digital games with learning purposes, additional aspects that are relevant for non-digital games for learning are identified as a result: social and tangible aspects. These should be considered for future analysis of non-digital games for GBL. Moreover, non-digital games are still underrepresented in serious games and games for learning, and invite more research on this topic.

The results of the game analysis, the reflection prompts specific to each game, are implemented in the double-survey structure around the DWI game workshops. This pre- and post-workshop surveys format has been received well by students and showed benefits in providing comparable data. However, the format might have had the unintended side-effect of students not recognizing the reflection activity as such.

By combining quantitative and qualitative data from overall 373 students' responses, the games and their learning effects were evaluated and discussed in detail, as well as students' feedback comments on the games workshops and the surveys including the reflection prompts. Overall, the games were evaluated positively in their learning effects and qualities. The students showed a favorable stance towards the games workshops and GBL, while also sharing insightful thoughts on the games themselves, organizational issues and details, and learning as well as GBL as a method.

In summary, the thesis has discussed and presented challenges and opportunities in GBL with non-digital games in Informatics education. Improvement suggestions specific to GBL in DWI were made, which can also serve as design considerations for future GBL activities and inspire (re-)design of games for GBL. Moreover, the area of non-digital games used in educational contexts can be further explored, especially since non-digital games facilitate player interaction in a natural way, which can further enhance and diversify learning experiences.

Overview of Generative AI Tools Used

Elicit.com was used to search and filter for appropriate literature for the literature review. I formulated questions such as “are there analogous games used in game-based learning?”, went through the papers found by Elicit, and expanded my literature research from those papers, using e.g., references in those papers, and looking for papers that have references these papers.

ChatGPT was used to create formulas for Microsoft Excel that I needed for the quantitative analysis of the survey responses. I described the data structure broadly and what I wanted to do with the data.

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