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Collective Reasoning – A Lecture Game for Deep Processing

Master's thesis in Computer Science
Supervisor: Alf Inge Wang
June 2023

Master's thesis

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Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

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Abstract

Encouraging students to perform *deep processing* is beneficial for society, as it fosters citizens who can understand and utilize knowledge in new situations, which is crucial to solving the problems of tomorrow. *Deep processing* is a way to process knowledge that results in a lasting understanding of concepts and their relations that learners can utilize in novel situations [1]. Norway's new national education curriculum framework promotes deep processing in education, but as with any other part of the curriculum, it can be challenging to motivate students with traditional teaching methods. Game-based learning is a promising technique for motivating students to learn, and could potentially be used to facilitate deep processing. A better understanding of the two fields' cross-section is needed for game-based learning to support deep processing in teaching practice.

To this end, we gather insight into the game-based learning method, as well as traditional learning theories and deep processing. Based on the combination of these insights, a learning game with game design elements that seems promising for facilitating deep processing is developed – the game *Collective Reasoning*. The game is used in experiments to evaluate its design and assess its ability to facilitate deep processing.

We found that existing theories on enjoyment and learning are a good starting point for designing learning games to facilitate deep processing, as they aligned well with the findings from the experiments. *Construction of argument graphs* and *self-guided exploration of information* are elements of the design that contributed to *Collective Reasoning* facilitating deep processing. *Score* and *competition* are game design elements that successfully motivated students to partake in the game.

Finally, our study indicates that learning games can successfully be used to incentivize deep processing among students. This is a promising finding for learning games concerning deep processing, and warrants further research on the crossroads between these fields.

Sammendrag

Å inspirere elever til å bruke *dybdelæring* er gunstig, fordi det beriker samfunnet med borgere som kan forstå og bruke kunnskap i nye situasjoner, noe som er avgjørende for å løse morgendagens problemer. *Dybdelæring* er å ta til seg kunnskap på en måte som fører til en varig forståelse av konsepter og deres relasjoner som elever er i stand til å bruke i nye situasjoner [1]. Norges nye læreplanverk legger fokus på dybdelæring i utdanningen, men som med alle andre deler av pensum kan det være utfordrende å motivere elever med tradisjonelle undervisningsmetoder. Spillbasert læring er en lovende teknikk for å motivere elever til å lære, og kan potensielt brukes til å dybdelæring. En bedre forståelse av hvordan de to feltenes kan kombineres er nødvendig for at spillbasert læring kan støtte dybdelæring i undervisningspraksis.

For å løse dette samler vi innsikt om spillbasert læring, samt tradisjonelle læringsteorier og dybdelæring. Ved å kombinere denne innsikten utviklet vi et læringsspill med spilldesignelementer som virker lovende for å legge til rette for dybdelæring – spillet *Collective Reasoning*. Spillet brukes i eksperimenter for å evaluere designet og vurdere spillets evne til å oppmuntre til dybdelæring.

Vi fant ut at eksisterende teorier om fornøyelse og læring er et godt utgangspunkt for å designe læringsspill for å oppmuntre til dybdelæring, da de stemte godt med funnene fra eksperimentene. *Konstruksjon av argumentgrafer* og *selvstyrt utforskning av fagfelt* er komponenter av designet som bidro til å gjøre dybdelæring enklere å benytte i *Collective Reasoning*. *Poengsystem* og *konkurranse* er spilldesignelementer som motiverte elevene til å delta i spillet.

Studiet vårt indikerer at læringsspill kan brukes til å stimulere til dybdelæring blant elever. Dette er et lovende funn for læringsspill om dybdelæring, og motiverer videre forskning på kombinasjonen av disse feltene.

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We would like to acknowledge and give a special thanks to our supervisor, professor Alf Inge Wang, at the Department of Computer Science at the Norwegian University of Science and Technology (NTNU), who made this work possible. His guidance and advice throughout the project have been invaluable.

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Part I

Introduction

This part introduces the project, its background, goal, and methodology. Chapter 1 presents the project's duration, location, and other attributes, and Chapter 2 outlines the motivation for the project, together constituting the project's background. Chapter 3 and Chapter 4 describe the project's goal and the methodology used to achieve it, respectively. This part concludes with a readers' guide describing the report's structure and how to navigate it. The motivation, methodology, and readers' guide chapters include adapted content from the specialization project associated with this master project [2].

1 | Project and Context

This report is for a master's thesis in the course *TDT4900 - Computer Science, Master's Thesis*. It is part of the master's program at the Department of Computer Science (IDI) at the Norwegian University of Science and Technology (NTNU). The project period was from 16.01.2023 to 12.06.2023, and the project continues the work from the specialization project initiated in the autumn of 2022 [2].

The task description formulated by the supervisor reads as follows:

Table 1.1: The project task.

Title	[Lecture Games] Collaborative classroom learning games 2022/2023
Description	The goal of this project is the design, implementation and evaluation of a collaborative learning game, where the students together beat the game and at the same time learn. The game will have to balance engagement and learning, to both make it fun and educational. Another requirement is that the game must be a multiplayer game where all the students in a class can participate at the same time.

The master's thesis continues where the specialization project [2] left off. Table 1.1 describes the entire project, the specialization project and the master's thesis. The specialization project consisted of a preliminary study, a presentation of multiple game concept ideas, and a selection of one of the game concepts which was promising for future research. The chosen game concept explores the idea of learning games inducing *deep processing*. The master's thesis continues the work by conducting research using a prototype of the game concept idea.

The work in the master project consists of four parts: the design, the implementation, the experimentation, and the evaluation of the game prototype. The **design** of the game prototype includes doing more research on the specifics of *deep processing*, and applying the general theories of learning and enjoyment found in the preliminary study to the game concept. The **implementation** consists of developing the prototype for the concept. The **experimentation** consists of planning and conducting experiments testing the prototype. The **evaluation** of the game prototype includes analyzing the experiment results and discussing the findings.

2 Motivation

Education is an essential societal function, and as technology improves and the field of pedagogy progresses, new opportunities emerge to utilize computers and electronics to improve learning.

Teachers and educators want to motivate learning and create efficient learning environments. Having motivated students is essential for learning, since "learners' motivation has been consistently linked to successful learning" [3]. The traditional classroom setting can be uninspiring for today's youth, as they are digital natives used to digital technology and entertainment [4]. A total of 86% of Norwegian children ages 9 to 18 regularly play video games [5], and digital games are recognized as "one of the most engaging forms of entertainment nowadays" [4]. The idea of taking inspiration from entertainment to improve learning is a way to combine the best of both worlds.

Game-based learning and *collaborative learning* are two fields shown to improve learning. Game-based learning is a teaching method that uses games to teach a subject, and interest in the field is on the rise; its usefulness over traditional teaching techniques is attributed to player enjoyment, engagement, and motivation [6]. Collaborative learning is a promising concept that actively involves students in the learning process. It can help students develop their social support system, build their diversity understanding, and promote critical thinking [7]. Collaborative learning can also increase students' self-esteem and academic results [7]. At the crossroads between these fields is *lecture games*, which is a promising new possibility that might retain the benefits of both [4].

A recent development in the Norwegian educational system is the introduction of a new national curriculum emphasizing deep processing [1]. *Deep processing* is a way to process knowledge that results in a lasting understanding of concepts and their relations that learners can utilize in novel situations [1]. This project explores whether games can support educators in facilitating deep processing – an emerging need – through game-based learning. This exploration includes framing deep processing in a game-based learning context and analyzing to what degree game-based learning literature can be applied to solve this problem.

We are motivated to explore the possibilities of game-based learning for deep processing to expand the frontier of knowledge related to game-based learning. We enjoy gaming and are interested in developing a lecture game that can be used for research, and we want to create a positive learning experience for students.

3 Research Goal and Questions

This chapter presents the purpose and contribution of this master thesis in the form of a research goal and four research questions. The research approach for this project incorporates the *Goal Question Metric* (GQM) approach [8]. GQM is a top-down approach, where the goal is defined first, followed by the questions that need to be answered to achieve the goal, and finally, the metrics that can be used to answer the questions [8]. Utilizing the GQM approach helps ensure that the research remains focused on its intended goal and that the research questions are pertinent. This project's research goal and questions have been formulated considering multiple factors, including the supervisor's task description and the specialization project's outcomes. Chapter 4 presents the metrics for answering the research questions.

3.1 Research Goal

The research goal of this project is:

> The goal is to explore inducing *deep processing* through *learning games* by designing and developing a *lecture game* inspired by *deep processing*, and assess the game's ability to *motivate learning* and *facilitate deep processing*.

3.2 Research Questions

Four research questions (RQs) have been formulated to break down the research goal. The research questions are relevant to the research goal and its underlying concepts.

RQ1: *How can a lecture game motivate learning?*
Research question 1 concerns how to motivate learning in a lecture game. The question should be answered by looking at how learning games can motivate learning through gameplay and how, if applicable, this is different for the subcategory of lecture games. Both the preliminary study and the evaluation of the game prototype can provide insights into how to motivate learning in lecture games.

RQ2: *How can a lecture game facilitate deep processing?*
Research question 2 focuses on how to facilitate deep processing in a lecture game – making it easier to use deep processing in the game. The question should be answered by combining deep processing literature with game-based learning theory, finding, implementing, and testing techniques to facilitate deep processing, and analyzing the requirements and process of designing a game to facilitate deep processing.

RQ3: *What are the characteristics of the deep processing facilitated by the developed lecture game?*
Research question 3 addresses whether the developed lecture game ascertains deep processing and, if so, what the characteristics of this deep processing are. The question should be answered by analyzing the experiment's results in the context of the theory of deep processing.

RQ4: *How well does the developed lecture game incentivize deep processing for individuals and classes?*
Research question 4 concerns how well the developed lecture game motivates and encourages deep processing. The question should be answered by looking at the game prototype's design elements and analyzing the experiment's results to see how well different design elements and factors contribute to incentivizing deep processing.

3.3 Summary

This chapter presented a research goal and four research questions that will guide the work and research in this project. The next chapter presents the methodology used to find answers to the research questions.

4 Research Methodology

This chapter presents the research process and methodology used in this project. The *Model of the Research Process* proposed by *Oates et al.* [9, p. 34] inspired the structure of this research process. Figure 4.1 visually presents the *Model of the Research Process*, highlighting the components used in this project.

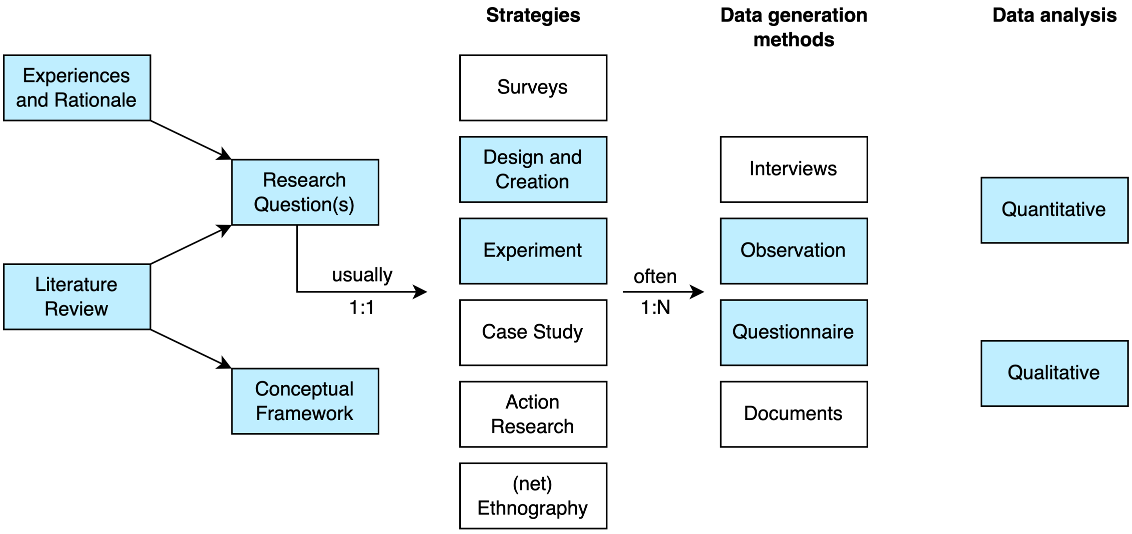

Figure 4.1: Research process model inspired by *Oates et al.* [9].

The work from the specialization project [2] serves as a base for this project's **research goal and questions**. The game concept ideas presented as part of the specialization project were based on the literature study and interviews of teachers. The selection process considered the research potential, personal motivation, and feasibility for all the concept ideas. The chosen game concept influenced the research goal and questions, as the game concept is the basis for the research. This approach to finding research goals and questions aligns with *Oates et al.*'s idea that **personal experiences, rationale**, and a **literature review** should be the basis for research questions [9].

The following sections describe the research process elements used in this project.

4.1 Literature Review

Studying relevant literature is essential to the research process [9, pp. 77–97]. The literature review in this project contributes to understanding the research fields and answering the research questions. The purposes of the literature review include: identifying relevant research, gaining knowledge about the research fields, contextualizing the research in this project, identifying existing research gaps, and identifying existing research potentials [9].

Literature for the preliminary study is selected based on its relevance to the research questions and the quality of the literature. The researchers are responsible for choosing the literature but consult with the supervisor, who suggests additional sources. To find relevant literature, the research group conducts searches using various research archives, such as Google Scholar and Web of Science. These searches include relevant concepts, keywords, and specific authors associated with the research fields. Some ways to determine the literature's quality are to look at the number of citations the research has received, the authors' reputation, the publishers' reputation, the age of the research, and the perceived quality of the research itself [9].

The literature review continued until the end of the project. A significant portion of the literature review was conducted as part of the specialization project [2]. However, a continuation of the literature review was performed in this project to gain a deeper understanding of the research fields and to find literature relevant to the research questions. The literature review from the specialization project was more general, so more specific literature was found for the research in this project, especially within the field of *deep processing*.

The literature review contributed to forming the **conceptual framework**. A conceptual framework "makes explicit how you structure your thinking about your research topic and the process undertaken" [9, p. 36]. The conceptual framework in this project includes the terms defined in the preliminary study used throughout the report, the research methods, and the strategies for gathering and analyzing data.

4.2 Strategies

The research strategies are the approaches used to answer the research questions [9, p. 37]. The strategies used in this project are *design and creation* and *experiment*.

Design and creation is a research strategy where the researcher designs and creates new IT artifacts [9, pp. 114–115]. An IT artifact can be many things, such as a product, a process, or a method [9, p. 115]. In this project, the IT artifact is a *lecture game* prototype. The game is designed and created as part of the master's thesis and is to be used in an experiment to contribute to answering the research questions. The game is designed and created based on findings from the preliminary study. The game implementation, including the development process and technical details, is described in Part V.

The **experiment** strategy is a research strategy where the researcher conducts experiments to answer the research questions [9, pp. 132–134]. Experiments are conducted to evaluate the game prototype. Chapter 21 describes the experiment design in detail. Students from two different upper secondary schools participate in the experiments, and multiple data generation methods are used to collect data.

4.3 Data Generation Methods

Data generation methods are the methods by which empirical data or evidence is produced [9, p. 38]. In this project, two data generation methods are utilized to get results to answer the research questions. The data generation methods used in this project are *questionnaires* and *observation*. Chapter 22 describes the data generation methods in detail.

A **questionnaire** is used as a data generation method to gather data from the experiment participants. A questionnaire is a data generation method with a pre-defined set of questions assembled in a predetermined order [9, p. 227]. The questionnaire is handed out to students after they have played the game. The questionnaire gathers information about the participants, such as gender and gaming habits, and asks questions about the game, such as how the students experienced the game and their perceived learning outcome from playing the game.

Observation is used as a data generation method to gather data from the experiments. Observation is a data generation method where one observes the participants' behavior and actions [9, pp. 211–213]. The teachers observe during the experiments, where they function as practitioner-researchers, meaning they function as researchers within their professional field [9, p. 218]. The teachers observe the participants' behavior and actions while they play the game and deliver feedback to the research group. The observation produces qualitative data from the teachers' notes. The teachers are good observers because they know the students and their behavior well.

Another type of observation performed during the experiments is observing the gameplay results. The students answer a session question during the gameplay by forming an *argument graph*. After the experiments, the researchers analyzed the answers to see how the students performed.

4.4 Data Analysis

After the data generation, the data needs to be analyzed to produce results that can contribute to answering the research questions. The data analysis is conducted both quantitatively and qualitatively. Quantitative data is data that is represented with numbers [9, p. 254], such as the number of students that answered each option in a multiple-choice question. Qualitative data is all data that is non-numerical [9, p. 275], such as student opinions or written statements.

The questionnaire contributes with both quantitative and qualitative data. Quantitative data from the questionnaire, such as the students' rating of their enjoyment of the game, is analyzed by calculating descriptive statistics, such as mean and coefficients, and creating graphs and charts to visualize the data. Qualitative data, such as the respondents' written feedback on the game, is analyzed by coding the data and identifying themes and patterns.

The Teacher's observations contribute with qualitative data in the form of their observations and feedback from the experiments. The experiments are only conducted with two teachers, so the data is not generalizable.

The observation of gameplay results contribute with qualitative data, which is analyzed to create quantitative data. The qualitative data is analyzed by coding the data and identifying signs of *deep processing*, as described in detail in Section 22.3. The gameplay results analysis creates quantitative data in the form of a score for each group of students. This quantitative data is analyzed by calculating descriptive statistics, such as mean and coefficients, and creating graphs and charts to visualize the data.

Data from different sources can be compared to find similarities, differences, and correlations. Comparing qualitative data from the questionnaire with the teachers' observation notes may reveal whether the students' opinions and behavior match the teachers' observations. The quantitative data from the questionnaire and the analysis of the game results can be compared to look for correlation.

4.5 Summary

The research methodology in this project consists of two research strategies and two data generation methods that result in quantitative and qualitative data. *Design and creation* and *experiments* are used in combination with observations and questionnaires to generate data that can be analyzed to answer the research questions. Later chapters describe the design and creation, experiments, and data generation methods in more detail.

5 | Readers' Guide

This chapter serves as a guide for the reader. It provides an overview of the report and explains how the report is structured.

Part I - Introduction

This part introduces the project and motivation for the project, as well as the research goal, questions, and methodology. This part is suited for readers interested in understanding the purpose of the project and the methods used to conduct the project. It is recommended to read this part to understand the project.

Part II - Preliminary Study

The Preliminary Study presents the theoretical basis for the project. The part includes relevant definitions for concepts used in the project, findings from teacher interviews, a study of relevant literature related to enjoyment and learning in games, theories on deep processing, and a presentation of relevant technologies.

Chapter 6 is crucial to read to understand later parts, as it defines concepts used in the project, so it is recommended to read this chapter before reading later parts of the report. Chapter 7 is focused on the findings from teacher interviews and is especially relevant for readers interested in understanding opportunities and challenges related to using learning games in Norwegian schools, as well as teachers' opinions on learning games. Chapter 8 and Chapter 9 present relevant literature related to enjoyment and learning in games and are recommended for readers interested in the theory behind games and learning. Chapter 10 focuses on deep processing. This chapter includes a section about *argument graphs*, which is a main element in the game concept developed in this thesis. This chapter should be read to understand the theory behind the game concept as well as the results of the experiments. Chapter 11 describes relevant technology for game development and is mainly relevant for readers interested in technology.

Part III - Game Concept Selection

This part presents the process of selecting the game concept. The part is mostly unchanged from the specialization project [2].

This part is optional to read, as one can understand the following parts without reading it. However, this part is recommended for those interested inthe process of selecting the game concept and those who want to understand why the game concept *Collective Reasoning* was chosen for this thesis. This part also presents other game concepts that were considered, which is interesting for readers interested in new game concepts for lecture games. The full version of this part contains a more detailed description of the selection process and is available in the specialization project [2].

Part IV - Game Concept Description

This part presents the chosen game concept – *Collective Reasoning*. Chapter 15 and the first three sections of Chapter 16 describe the game concept and are essential to read to understand the experiments and results. The rest of the sections in Chapter 16 describe the game concept in more detail and are recommended for readers who want to see the user interface and learn more about the game concept. Chapter 17 and Chapter 18 elaborate on the game concept and describe how the theories presented in the preliminary study are applied to the game concept. These chapters give insight into the thought process behind the game concept and how the game design should promote enjoyment and deep processing.

Part V - Game Concept Implementation

This part describes how *Collective Reasoning* was implemented, including the development methodology and the technology solution. It is not necessary to read this part to understand the game concept. This part is recommended for readers interested in understanding the game implementation, and can be used as a reference for readers who want to develop a similar game.

Part V - Experiment

This part describes the experiments conducted as part of this project. It also describes the analysis of the results and the reliability and validity of the experiments. It is recommended to read this part to understand the experiments and the results. The results are a direct result of the experiments, so reading this part provides more context to the results.

Part VI - Results

This part presents the results of the experiments. It is recommended to read the results before reading the discussion of the results to get a more objective view of the results. However, it is not necessary to read this part to understand the discussion of the results, as the discussion chapter mentions the parts of the result that are relevant to the discussion.

Part VII - Reflection and Conclusion

This part presents the reflection of the project and concludes the project. Chapter 28 includes a discussion of the results. The discussion is where the research questions are answered, so it is recommended to read this part to understand the project's outcome. The conclusion in Chapter 29 summarizes the project's findings. Chapter 30 is a project retrospective and is recommended for readers interested in the project process. The chapter discusses choices and compromises made during the project and can be helpful for readers interested in conducting a similar project. Chapter 31 presents suggestions for further work and is interesting for readers who wish to continue the work of this project or conduct other projects on deep processing in learning games.

Part II

Preliminary Study

This part represents the preliminary study of the project. The preliminary study aims to explore the research fields of *game-based learning* and *deep processing*, as well as investigate teaching practice as a context for *learning games*, all in pursuit of achieving the research goal. This includes (1) finding relevant concepts, methods, models, and frameworks, (2) contextualizing this study in the respective fields through analysis of their direction and challenges, (3) gathering circumstances from secondary school that are relevant for experimentation and, afterward, analysis, and (4) partially answering research questions *RQ1* and *RQ2*. The preliminary study gathers findings from the literature review and interviews with teachers and is based on the preliminary study of the specialization project associated with this master project [2]. Chapter 6, Chapter 8, and Chapter 9 have been reworked and expanded to better define concepts from, and state of, the *game-based learning* field, as well as more appropriately frame a selection of the presented studies. Chapter 10, describing the field of *deep processing*, is new and, therefore, not an expansion of a chapter in the specialization project. The presentation and readability of Chapter 7 and Chapter 11, which present interview findings and relevant technology, respectively, have been improved compared to the specialization project, but the content is mostly the same.

6 | Game-Based Learning

The research in this thesis is centered around the use of games in education, specifically *lecture games*, and aims to contribute to the field of *game-based learning* (GBL). This chapter introduces the field of game-based learning, and presents the terms *learning game*, *lecture game*, *gamification*, *multiplayer game*, and *asymmetric game*, which are relevant to the research in this thesis. Examples are used to illustrate the terms. Some concepts and terms are only briefly introduced in this chapter, as they are further elaborated in later chapters.

6.1 What is Game-Based Learning?

In the article "Digital Game-Based Learning" from 2003, *Marc Presensky* argues that "Video games is not the enemy, but the best opportunity we have to engage our kids in learning" [10]. Successful learning is more likely to happen when the learner is motivated, and in the video game industry, **motivation itself** is the key expertise [10]. By combining the expertise of the video game industry with the expertise of the education industry, the result is a way of teaching called *game-based learning* [10].

The expression *game-based learning* describes **a teaching method where games are utilized as a medium to teach the players something** [10–13]. To complete this definition of GBL, it is necessary also to define what a game is. Many authors list characteristics they think must be present for play to be called a game. Five recurring characteristics are listed: (1) Games include an **agonistic dimension**, either a conflict between the player and the game systems or with other players [13, 14]. (2) Games are frivolous and **non-productive** [11, 13]. (3) **Game rules** define what players can and can not do in a game. Game rules serve as the basis for player interaction with the game and player autonomy [11, 13, 14], (4) as does the fact that games have an **uncertain outcome** [11, 13]. (5) Gameplay is **separated** in time and space, with boundaries to the *real world* [11, 14].

The goal of the GBL method is to use games to enhance the learning experience by encouraging students to participate in learning while playing, thereby making the learning process more exciting and motivating for students [11]. Engagement and fun are, therefore, of utmost importance for GBL. Educators can use the method to teach various subjects, such as mathematics, science, history, and language [13], but it may also be used to aid in teaching students skills, such as how to solve problems or work together [10].

To date, much research has been done regarding the effectiveness of GBL in various domains and settings [15, 16]. There have been conducted reviews on GBL's effectiveness in memorization, knowledge acquisition, and problem-solving skills, among other domains [15]. However, no consensus has been reached with respect to the positive effect of game-based learning, as the results of using the GBL method are mixed [15]. There exist some critical objections to the state of the field of research. *Westera* compiles a list of ten premises or stances of proponents of GBL that can be misleading if one ignores when and why they apply, such as "games foster motivation" and "games support learning-by-doing" [17]. *Camilleri* presents a summary of the costs and pitfalls of utilizing GBL, including funding constraints as barriers to technology integration and the introduction of the need for teachers to improve their digital literacy. This workload does not directly contribute to teaching [18].

6.2 Learning Games and Lecture Games

The game prototype developed in this project is a *lecture game*, which is a sub-category of *learning games* [11]. These expressions are defined in this section.

There exist differing definitions of learning games, but a shared understanding is that **they are games designed to have a learning purpose** [11, 19]. Using learning games is the most evident way to implement GBL [12], but other games may also be utilized in GBL, given that the game is used in a way that is beneficial for the learning process [11].

Learning games that are designed to be suitable for lectures in a classroom setting are called lecture games [20]. To be suitable for use in lectures, the game should be played in a limited amount of time, such as the duration of a lecture, and should be designed to be played by multiple players, such as a class of students.

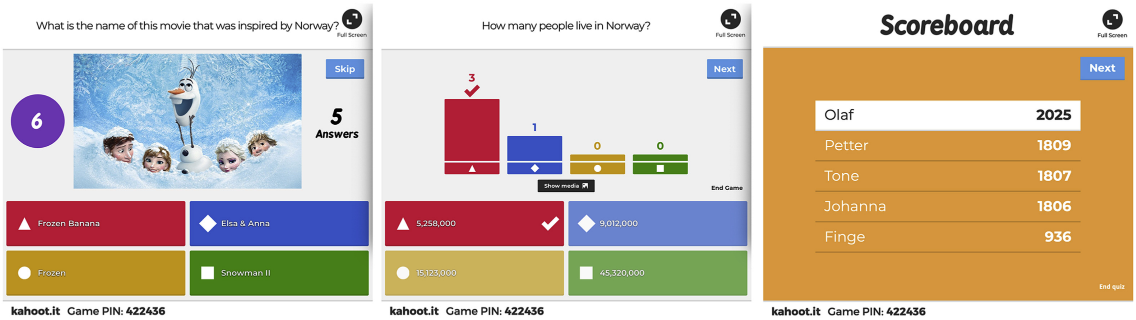

Figure 6.1: *Kahoot!*: Screenshots from answering, distribution of answers, and scoreboard [21].

An example of a game-based learning platform is *Kahoot!*, where teachers can create lecture games. Figure 6.1 shows screenshots from a *Kahoot!*-game. A game created using *Kahoot!* consists of multiple choice questions visible on a screen viewable to all players, such as a projector in a classroom. The players answer the questions by selecting the correct answer on their individual devices and get points for answering correctly. A literature review of research done on *Kahoot!* concludes that the platform "can have a positive effect on learning compared to traditional learning and other learning tools and approaches" [21], which is a positive indicator for the use of GBL in education. One of the studies reviewed in the literature review has shown that points and audio in *Kahoot!* positively affect engagement, which is a further positive indicator for the use of GBL [22]. The research on points and audio in *Kahoot!* is elaborated in Chapter 8 as part of the literature review on enjoyment in games.

6.3 Categories of Learning Content

This section presents two ways of categorizing the *learning content* of learning games. The categories provide a way to classify *learning outcomes*, making it easier to understand and differentiate between different *lecture games* presented as part of the thesis. The categories have been identified by looking at the different learning games and identifying commonalities between them, and examples are included to illustrate the categories. The two ways of categorizing are directly related to the learning outcome of the game, as this helps determent how games foster learning. There are multiple other ways to categorize learning games that are not presented here, such as categorization by *game genre* [23], but they are less relevant to the research of this thesis.

One way to differentiate learning content in learning games is based on whether it is inherently tied to the objectives presented to the players of the game or not. If, when pursuing the player's primary objectives, learning some learning content in the game is unavoidable, the learning that takes place is referred to as a **primary learning effect** of the game. Regarding such a learning effect, since it is so relevant to the gameplay, players are often aware of the role learning plays in the game. An example of a game with a primary learning effect is *Kahoot!*, where learning the subject of the questions – performed before or during the gameplay – is fundamental for performing well in the game. On the other hand, when learning content is present in a game, but it is not strictly necessary to learn it when pursuing the objectives of the game, the effect on the learning outcome is referred to as a **secondary learning effect**. In these games, the players may be less conscious of the role of learning in the game, and the learning effects materialize from passive exposure to facts and circumstances. An example of such a game is the game *A Total War Saga: TROY*, where the players are not required to learn anything useful to succeed in the game, but the game is set in ancient Greece, and the player is exposed to the history of the time period. A game can have learning content with a *primary learning effect* and different learning content with a *secondary learning effect* at the same time.

Learning content may also be differentiated based on whether it is *specific* or *flexible*. Predefined and static learning content in a game that is called **specific learning content**. For example, a game may be designed to teach a specific part of a curriculum, such as differential equations in mathematics or the French Revolution in history. A game can be said to support **flexible learning content** if the game allows an educator to adapt the game to fit the learning outcome they want to achieve through customized learning content. Many quiz-like games have flexible learning content, such as *Kahoot!*, where the questions used can be customized to fit the curriculum. A game can support both *specific* and *flexible* learning content at the same time.

6.4 Gamification

Gamification refers to "the use of game design elements in non-game contexts" [24]. The idea of gamification is to use game design elements to motivate users to perform specific actions [24]. Such desired actions could be students engaging in learning activities, but it could also be employees engaging in work. The distinction between gamification and GBL is that gamification is the use of game elements in non-game contexts, while game-based learning is the use of game elements to create gameplay in learning contexts [24]. While gamification of an already existing math learning activity can introduce points and badges to motivate students, when utilizing GBL, one would have to redesign the learning activity to include *game rules* and *artificial conflict*, among other things, to call it a game [12]. Examples of game elements that may be used for gamification are *points*, *badges*, *levels*, and *leaderboards* [24].

In the context of education, gamification is the use of game elements to motivate students to learn [25]. Examples of gamification of education are giving points to students for completing assignments or giving badges to students for completing a course. Gamification is a way of motivating students to learn [25]. Gamification may be done using physical tools, such as handing out medals to students or using digital learning tools which automatically give points or badges to students. In contrast to a learning game, a gamified learning tool is not necessarily designed to teach the students something, but rather to motivate the students to learn. In some cases determining which category a learning tool belongs to is not straightforward, as both learning games and gamified learning tools are based on the same idea of using game elements to facilitate learning. The same theories of enjoyment, which are discussed in Chapter 8, can be used in both learning games and gamified learning tools.

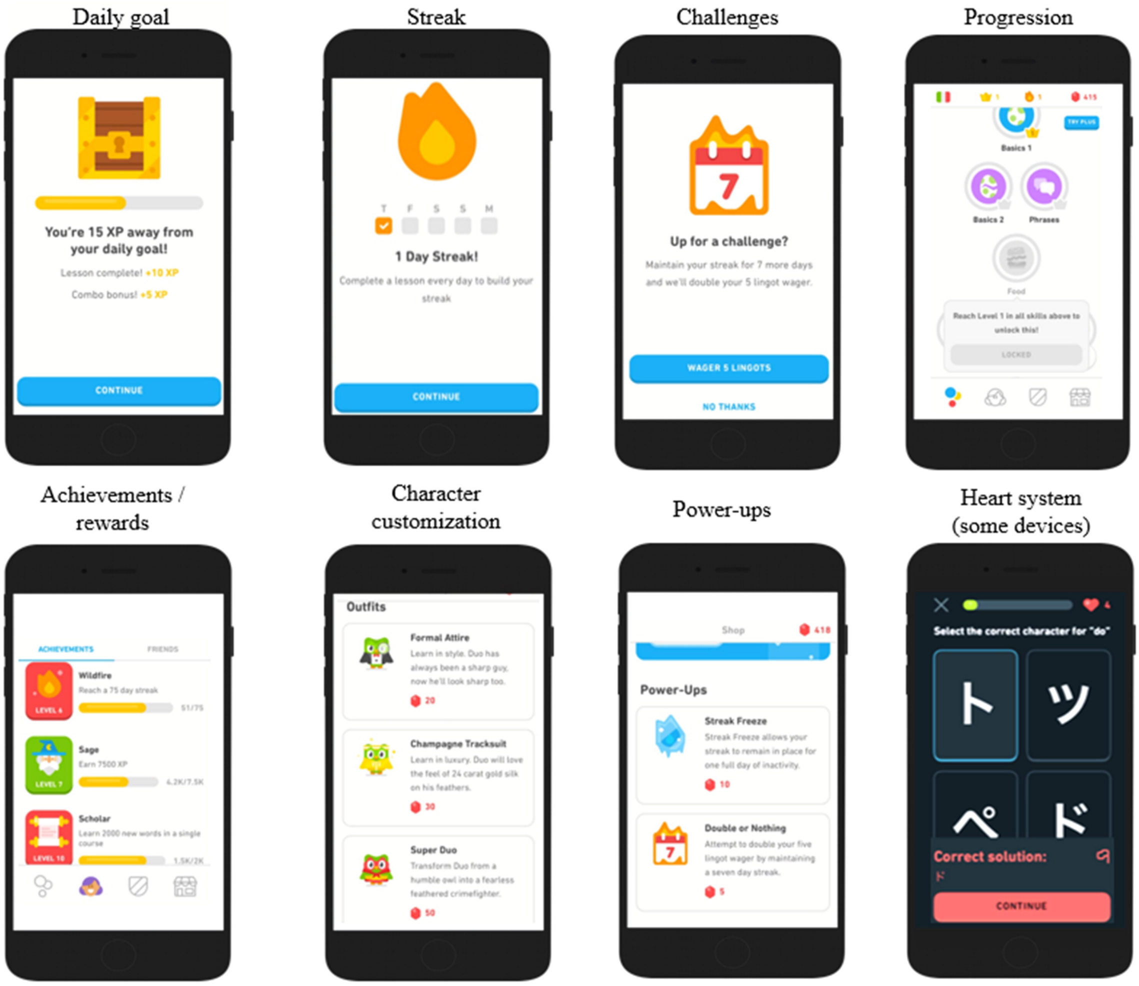

Figure 6.2: Screenshots from *Duolingo*'s gamification elements [26].

An example of a gamified learning tool is *Duolingo*, which is a language learning tool that uses gamification elements to motivate users to learn a language [27]. *Duolingo* uses multiple gamification elements, as seen in Figure 6.2, to motivate the users to learn a language [26], but the learning activities themselves – among other things, multiple choice translation questions and listening exercises – are the same as traditional education.

6.5 Multiplayer Games

A *multiplayer game* is a game that is designed to be played by multiple players, and the players interact with each other in some way. There are multiple ways to categorize multiplayer games, such as by the number of players, the type of interaction between the players, and the type of interaction between the players and the game. In this thesis, the focus is on the type of multiplayer game elements most relevant for lecture games.

Some of the ways to categorize multiplayer games and multiplayer elements in games are based on how the players interact with each other and how they interact with devices. The players can **interact** with each other in a *competitive* way, such as in a game of chess, or in a *collaborative* way, such as teammates in a game of football [28]. Multiplayer games can be played by multiple players on the same **device**, such as players using different buttons on a keyboard connected to a computer, or by multiple players on different devices, such as players playing on their own mobile phones. Multiplayer games can be played by multiple players gathered in one physical **location**, or by multiple players in different physical locations [29]. Their physical location may be relevant for the game, as it affects their ability to interact with each other [29]. Multiplayer games differ in **pacing** – they can be played in real-time, meaning all players are playing at the same time, or turn-based, meaning the players take turns playing the game [30].

Asymmetric games are a type of multiplayer games that support fundamentally different gameplay by different players. It is *interaction* and *interdependence* between players that can create asymmetric gameplay. *Harris et al.* present a non-exhaustive list of **six mechanisms through which asymmetry can arise** [31]: (1) Asymmetry of Ability, when a player can do actions another player cannot; (2) Asymmetry of Challenge, when the challenges players face are different in nature; (3) Asymmetry of Interface, when input-output modalities, or ways players interact with the game, are different; (4) Asymmetry of Information, when a player knows something another player does not; (5) Asymmetry of Investment, when players invest a differing amount of time to their roles; and (6) Asymmetry of Goal/Responsibility, when players seek to achieve different outcomes. Likewise, they **classify interdependence into three categories by nature of directionality** [31]: (1) *Mirrored Dependence*, also just called teamwork, when players rely on each other to contribute toward the same objective in the same way; (2) *Unidirectional Dependence*, when one player relies on another, but the other player does not rely on something back; (3) *Bidirectional Dependence*, also called symbiosis, when two players rely on each other, but in different ways. Both interdependence and the difference in gameplay are needed to make the gameplay asymmetric; without the interaction between the players, the players are simply playing different games.

The multiplayer elements most suitable for lecture games are real-time multiplayer games where the players are sitting in the same physical location and playing either on the same device or on individual devices. As lectures occur in a classroom setting, the players are physically co-located, enabling communication and interactions between the players. Real-time multiplayer games are games where all players are playing at the same time, which is suitable for a classroom setting, as the players are gathered for a limited time. A quick-pace turn-based game could also be suitable, but as the players are all present at the same time and a limited amount of time is available, a real-time multiplayer game where all students can be playing at the same time is most natural. The students can play on the same device or on individual devices. What devices are available in Norwegian classrooms specifically is relevant as this is the testing arena for the game developed in this thesis, and it is discussed in Chapter 7.

Competitive, cooperative, and asymmetric games are all suitable for lecture games, as they all support interaction between the students, but the type of interaction may affect both the level of enjoyment and the learning outcome of the game. How the students interact with each other as part of the game will affect their experience with the game, and the effect it has on enjoyment and learning is discussed in Chapter 8 and Chapter 9, respectively.

6.6 Summary

This chapter included definitions for game-based learning, learning games, lecture games, multiplayer games, and asymmetric games and presented two dimensions for the classification of learning games. All teaching using games as tools can be categorized as GBL, and when a game is designed to have a learning effect, it is a learning game. If a learning game is designed for a classroom setting, it is called a lecture game. Learning effect may be classified based on whether the learning is tied to the in-game goals – primary and secondary learning effect – and learning content can be specific or flexible. The use of game design elements in non-game contexts is called gamification, and learning may be gamified by applying game design elements to learning activities. Multiplayer games are games where multiple players play the same game and interact in the game. There are multiple ways to categorize multiplayer games based on how the players interact with each other and the game.

7 | Teacher Interview Findings

This chapter presents findings from interviews with teachers at four schools from two different municipalities. In each municipality, one lower secondary school and one upper secondary school were visited. The interviews were used to gather qualitative data and are partially used for discovery. Many of the findings are based on teachers' intuition and anecdotal experiences. All findings presented in this chapter can also be found in Appendix A. This chapter presents the interview findings and ends with a summary of the findings.

7.1 Electronic Devices and Infrastructure

The interviews reflect that schools are different regarding what devices they use and what capabilities their classrooms have to support electronic devices. These circumstances affect the *learning games* that can be deployed at each school.

All teachers indicated that the **WiFi coverage at their school is currently mostly satisfactory**, and some indicated that it had improved a lot in the last few years. In three out of four schools, however, teachers mentioned that the internet access could be temporarily down because of upgrades to the internet infrastructure, accidents in other infrastructure projects in the area, or similar events, but this was rare.

The **number of power sockets available varies** significantly based on the school and the classroom within the school. Most classrooms have rather few power sockets. Teachers at the upper secondary schools mentioned having socket extensions on wheels to mitigate this problem. One of the lower secondary schools mitigated the problem by requiring that students charge the batteries of their devices at home, and the other lower secondary school mentioned their problem with the battery capacity of their devices but did not mention any mitigation strategies.

All schools aim to provide their students with **electronic devices**, either by lending or handing them out. One school initially procured enough *Chromebooks*, but over the years, their fleet shrank. Now, some 8th-grade students must share their *Chromebook* in pairs. The other lower secondary school lend out *iPads* instead. At this school, it was not mentioned that the number of devices was a problem. For the two upper secondary schools, the county – a bigger administrative region than the municipalities – is responsible for supplying students with *Windows laptops*. However, not all students use the county's offer, and some students attend class with personal *tablets* or *Mac laptops* instead.

All schools had a solution for teachers and students to present content on a **big screen** to the class. Two schools use *SMART Board* products that support cable standards like HDMI, VGA, and jack plugs. One of the teachers at one of these schools mentioned that one of their *SMART Boards* was broken and could not reproduce colors correctly, while in another classroom, the audio solution did not work. It is an interesting finding that even these important systems, which there are few of in a school, are not that reliable. One school uses another brand of smart board based on the *Android operating system*. The last school uses traditional image projectors; unlike all the other schools, this solution does not include a pointing input feature.

7.2 Device Usage and Compatibility

The utilization of **electronics in the school setting is on the rise**. Multiple teachers stated that students would rather write on their electronic devices than by hand, and others commented that they are interested in computers and want to use them more. Phones, tablets, and computers are successfully used in learning activities today, like playing learning games, writing, and looking for information on the internet.

In general, teachers aim to **limit electronics usage in the classroom unrelated to learning activities**; this is true for both computers and phones, and teachers must keep an eye open. When asked about **distraction** associated with electronics, teachers say that it does not need to be treated differently than during other teaching activities; the students will manage to be distracted by anything if they want – like a hare running past the window. If anything, an especially engaging learning game might retain students' attention better. On the other hand, while the internet inherently invites distraction, the notifications of mobile phones are especially unfortunate. Some schools utilize a concept called "Mobile hotels" – the students leave their phones in a place where they do not have access to them during classes – and some teachers want to limit the usage of mobile phones during class in general.

Many software applications cannot be used in the classroom setting for different reasons. The most obvious problem that may arise is compatibility issues between the operating systems of students' devices and potential software. This is especially problematic at the secondary school level, since some students bring their own hardware. However, software that ultimately ends up being used does not need to fit perfectly in this regard; students can, for example, use devices in pairs if some students have incompatible devices. The process of distributing an application can, in some school systems, be quite bureaucratic. At one interviewed school, a candidate application needed to be screened for security concerns, can not contain ads, and distributed to devices with limited storage, all of which a teacher does not have much influence over. In addition, the acquisition or training for teachers in using the application might need to be financed.

7.3 Teacher Intuition on Learning Outcome

Many teachers think **learning games can contribute to learning outcomes through motivation**. Three mechanisms stood out in the interviews: (1) They can be engaging and fun, causing the students to focus on the goals of the game, and through this, cause students to learn subconsciously if the goals require learning; (2) learning games, or games in general, can serve as a reward when individuals or the class are done with other school activities; (3) learning games can, through rewarding good performance in accordance with competence aims of the curriculum, make the students want to learn. All three mechanisms rely on the ability of the learning game to engage and entertain the students, and mechanisms (1) and (3) can even cause the students to learn in their free time.

A number of findings are related to **engagement** in learning games. Teachers have observed that many students, especially boys, are very motivated by competitive elements in the learning games they have employed. On the other hand, a strength of learning games is the potential to appear less threatening and to have a low barrier to entry for participating in collaborative school activities. Students will find little reason not to participate when they are presented with an explicit goal, and participation is as easy as pressing UI buttons on their own screen. This might not be the case if, on the other hand, the social stakes were higher, for example, by having the worst performers be exposed to the whole class.

Almost universally, teachers highlight the importance of **variation** in school activities. However, teachers rarely explained why. One teacher stated that it helps keep school activities interesting for the students. Still, the prevalence of this sentiment cements it as an important finding. This sentiment was also evident in other comments; for example, teachers answered that games with both flexible and specific learning content have their role in education. In one case, the learning game *Kahoot!* had been used too much in a short period of time, causing the students to lose interest. On the other side, when a learning game is first introduced, students use some time to learn about the game itself – like its controls and goals – instead of the intended learning content. The effort, time, and preparation required to employ a learning game should be minimized. Still, it can be justified by a good learning outcome or the ability to be employed sporadically for variation.

7.4 The Norwegian Curriculum

A **new version of the *Norwegian national curriculum*** has recently been introduced. Teachers have shared several changes associated with this new curriculum relevant to their own practice, a few of which will be presented here. Firstly, programming was introduced into the math subject and the natural sciences subject. Multiple teachers in these subjects stated they are unsure whether they are able to teach this topic well, a topic and skill they have little experience with. Secondly, the new curriculum puts emphasis on the concept of *deep processing*, where students understand deeper connections in the material and are able to apply it in novel situations [1]. This concept will be described in more detail later. In addition, three multidisciplinary topics have been introduced that are meant to illuminate the contemporary challenges of society, as well as serve as connections between different subjects [32]. The three multidisciplinary topics are (1) sustainable development, (2) democracy and citizenship, and (3) health and life skills [33]. One teacher commented that a bigger part of the learning content of the national curriculum could be covered if a learning game tried to tackle one of the multidisciplinary topics instead of being limited to one topic in one subject.

7.5 Summary

The circumstances relevant to learning games in lower secondary schools and upper secondary schools in Norway have been explored through teacher interviews. Some main findings relevant to designing lecture games for Norwegian schools are the following:

- Most schools have reliable internet access.
- Most students have access to an electronic device in the classroom, but not all devices are compatible with all software.
- Most classrooms are equipped with a digital presentation screen.
- Many students are motivated by competition.
- Many students enjoy using electronic devices in school.
- Teachers are interested in using learning games and lecture games and believe they can contribute to learning outcomes.
- Motivations for using learning games in schools are that games can be engaging, fun, and a source of variation in school activities.
- The new national curriculum in Norway introduces programming into core subjects and emphasizes deep processing and multidisciplinary topics.

8 | Theories of Enjoyment in Games

As mentioned in Chapter 6, enhancing the learning experience and making the learning process more interesting for the students are critical factors for success when using the *game-based learning* method. Therefore ensuring that the students enjoy the gameplay is essential for the method to work. This chapter will present theories of enjoyment in games relevant to GBL that can be used to design enjoyable learning game concepts for students.

8.1 Challenge, Fantasy, and Curiosity

In the article "What makes things fun to learn? Heuristics for Designing Instructional Computer Games" [34], *Thomas W. Malone* argues that the most important aspects of enjoyment in computer games can be organized into three categories: Challenge, Fantasy, and Curiosity. The article describes *Malone*'s intuition about what makes games fun and how these aspects can be applied to the design of computer games. The three aspects of enjoyment are not mutually exclusive, and they can be combined in different ways to create different types of games. This section describes the three aspects of enjoyment presented by Malone, and for each aspect, there is a discussion on how it can be applied in *learning games* to contribute to a learning outcome.

8.1.1 Challenge

The challenge aspect of a game is related to the game engaging the player's **self-esteem** by providing **goals** and **uncertainty of outcome**. A game can be enjoyable by providing goals that are difficult enough to be interesting, but not so difficult that they are impossible to achieve. The uncertainty of the outcome is related to the fact that the player does not know if they will succeed or fail, and that the outcome is not predetermined. This uncertainty can engage the player in the game. Upon success, the player should feel a sense of accomplishment and feel better about themselves. On the other hand, if the player fails, they may feel a sense of frustration, which over time can be demotivating, so the game needs to be at an appropriate difficulty level for the player to be enjoyable [34].

Different game design choices can be made to ensure that the game is at an appropriate difficulty level for the player. When it comes to presenting goals, the game should be designed so that the player can perceive the goal, and the player should be able to see their progress towards the goal. Goals may be split into **multiple levels**, such as a primary goal of reaching a score and a more challenging meta-goal of reaching it within a time limit. Multi-level goals let the player choose a goal to focus on, which can help keep the game experience challenging for players at different skill levels. The same can be achieved by designing a game with **variable difficulty levels**, where either the game tries to predict a fitting difficulty level for the player or the player is allowed to choose a difficulty level. Uncertainty of outcome can be ensured by introducing **hidden information**, such as not presenting the number of enemies in a room, or by introducing **randomness**, such as the value of a dice rolled in a dice game [34].

Challenge in Learning Games

Challenge can be tied to the learning outcome of a learning game by making learning a part of the challenge. If a game has a *primary learning effect*, the goal of the game should be directly tied to the desired learning outcome, for example, by giving the player points for doing a correct multiplication in a math learning game. If the game has a *secondary learning effect*, the goal can be more loosely tied to the learning outcome. One example of this is *A Total War Saga: TROY*, in which the player can use knowledge of Greek mythology, such as knowing that Ares is the god of war and courage, to gain an advantage in the game. It can, for example, indicate the potential use of items and power-ups from their name at a glance, that players without this knowledge would have to research more thoroughly to find out, but it does not directly give the player progress toward the goal of winning the game.

In a lecture game, the game's challenge may also be related to competing with other students either in groups or as individuals, which teachers indicated is a significant motivation factor for many students (see Chapter 7). By competing with other students, the game can appeal to the player's self-esteem, and the player may feel a sense of accomplishment upon success. Competition makes the players more uncertain of the outcome, as they do not know how the other players will perform. If there is live tracking of points, the players can also see their ranking compared to other players during the play session, which can help keep the game experience challenging and interesting, as the goal of beating other players may become increasingly difficult as all the players improve.

8.1.2 Fantasy

Fantasy refers to showing or evoking images of objects or situations that are not present, and can make computer games more interesting [34]. Fantasies may present objects or situations that are completely possible, such as a fantasy of the player walking down the street, or they may present objects or situations that are completely impossible, such as a fantasy of the player being a superhero.

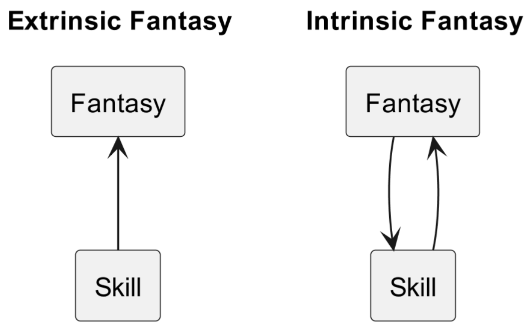

Figure 8.1: The relationship between fantasy and skill in extrinsic and intrinsic fantasy [34].

Malone distinguishes between **extrinsic fantasies** and **intrinsic fantasies**, which differ in how the fantasy depends on skill use, as seen in Figure 8.1. In intrinsic fantasy, skill use and fantasy depend on each other and are not separable. Usually, intrinsic fantasies are created by having problems presented in terms of the elements of the fantasy world, and the fantasy world events usually depend on how the skill is used and emphasize how its use is different from the correct usage. In extrinsic fantasies, the fantasy depends on the use of skill, but not vice versa. Extrinsic fantasies have the advantage that they are domain-independent. Malone argues that intrinsic fantasies are generally more interesting because the fantasy in a game is intimately related to the material being learned, and the player can see the connection between the fantasy and the skill being used [34].

Fantasy in Learning Games

Fantasy can be used to create a learning game that is interesting for the players. Intrinsic fantasies are suitable for games with *specific learning content*, as the fantasy can be directly related to the learning content. As extrinsic fantasies are domain-independent, they can be used to create a fantasy world that is not directly related to the learning content and is more suitable for games with *flexible learning content*.

In a lecture game, a fantasy can create a fictitious social situation that all the students are a part of. Fantasy can help distinguish the game from a regular lecture, which can help provide a varied learning experience for the students, which teachers indicated is important for keeping the students motivated (see Chapter 7). Teachers also mentioned that participating in a learning game can be less intimidating than participating in other learning activities for some students, and fantasy can help make the students feel more comfortable with participating in the game. Being placed in a fantasy world can help the students feel more comfortable with making mistakes, as they are less connected to the real-world setting.

8.1.3 Curiosity

Curiosity is a strong desire to know or learn something. Curiosity is independent of any goal-seeking or fantasy-fulfillment in games and can be evoked by providing an environment with an ideal level of complexity. The environment should be complex enough to be interesting, but not so complex that it is overwhelming [34].

Malone divides curiosity into two types: **sensory curiosity** and **cognitive curiosity**. Sensory curiosity is related to the player's desire and curiosity to explore the environment, and games can appeal to sensory curiosity through audio and visual effects. Cognitive curiosity is related to the player's desire to understand the environment. Games can appeal to this desire by providing a sense of mystery and letting the player explore to unlock complete and consistent information or knowledge [34].

Curiosity in Learning Games

By evoking curiosity, a learning game can cause the student to learn through exploration of the game. The teachers interviewed in Chapter 7 argued that learning games can be good at teaching the students without them realizing it, and curiosity can be used to achieve this. By creating a sense of mystery or intrigue, players can be motivated to explore and learn in order to satisfy their curiosity while subconsciously learning. Both sensory and cognitive curiosity can be utilized to create an exciting learning environment for the students.

8.2 GameFlow

The *GameFlow* model is a model for player enjoyment in games based on the concept of *Flow* [35]. Flow is a state of mind where the person is in a state of "optimal experience", where they are fully immersed in an experience, completely focused on the experience, do not think about anything else, and are unaware of the passage of time [36]. Flow theory is based on the premise that the elements of enjoyment are universal.

The eight elements of the original Flow-theory:

1. A task that can be completed.
2. Ability to concentrate on the task.

3. The task has clear goals.
4. The task provides immediate feedback.
5. A deep but effortless involvement that removes awareness of frustrations of everyday life.
6. The ability to exercise a sense of control over actions.
7. Concern for the self disappears, but a stronger sense of self emerges afterward.
8. The sense of duration of time is altered.

In 2005, *Sweetser* and *Wyeth* published a major literature review that mapped the elements of the Flow model to preexisting concepts and research in the video game literature [35]. This resulted in a model that can be used to design and evaluate games with respect to player enjoyment [35]. Major adaptions needed to fit the Flow model to the game literature were as follows: (1) removing the element of a task to be completed since this is the game itself, but adding the two elements of *challenge* and *player skill* to represent something similar, (2) combining the elements of deep and effortless involvement, loss of self-concern and altered time perception into the element of *immersion*, (3) adding the element of *social interaction*, (4) keeping the elements of *concentration*, *control*, *clear goals* and *feedback* with updated game related descriptions [35].

This section describes the eight elements of the GameFlow model, which each include an overall goal and a set of central criteria that can be used to design and evaluate games with respect to player enjoyment.

8.2.1 Concentration

The element of concentration is related to the game requiring focus and the player being able to concentrate on the game. The idea is that the more concentration a game requires, the more absorbing it will be. When a game requires the player to use all their relevant skills to cope with the challenges presented by the game, there is no excess energy left for the player to think about anything else. The central criteria for concentration are that the game should provide stimuli worth attending to, grab the player's attention, maintain the player's focus, be appropriate for the player's limits, and not distract them from tasks they want or need to concentrate on.

8.2.2 Challenge

Games should be appropriately challenging. Games create enjoyment by providing a challenge to the player, which result in intrinsic rewards for the player as challenges are completed. A central criterion is that a challenge is difficult enough to be interesting, but not so challenging that it is impossible to achieve. Other criteria relating to challenge are that the game should provide different levels of challenge for different players, the level of challenge should increase as the player progresses, and the game should present new challenges at an appropriate pace.

8.2.3 Player Skills

A game should support the player's skill development and mastery. A player's skills must match the perceived challenge provided by the game, and both challenge and skills should exceed a certain threshold. To ensure that a game is enjoyable from the beginning, learning the game should not be boring. Learning a game should not require reading a manual. The game should rather provide an in-game tutorial or, in another way, ensure that learning the game is part of the fun. Making design choices consistent with platform conventions and following game design trends can also make the interface and mechanics of the game easier to learn. Games should also include in-game help wherever possible, so exiting the game is not required. Just like the difficulty level of challenges, as mentioned in the Challenge section, required player skill should also increase as the player progresses in the game.

8.2.4 Control

The player should feel a sense of control over their actions in the game, like they are playing the game, not being played by it. In a game where the player is portrayed as a character, control in the game can refer to control over the movement and interactions of the character in the game world. In general, control can refer to control over the game's interface and mechanics and the player's ability to adequately translate their intentions into actions in the game. Control in the game includes control over the game shell, meaning the player should be able to start, stop, and save the game and be able to customize the controls and settings of the game. Another central aspect to control is that the player should be faced with decisions they need to make, where their choices affect the outcome of the game. Games should hide that the player is being limited or directed, allowing the player to feel they are making choices and that their choices are leading to unique outcomes.

8.2.5 Clear Goals

Games should provide the player with clear goals presented at the right time. Clear goals ensure the player has direction and is never left without anything to do. The timing and the presentation of the goal must be well thought out, and the player should experience that the goal is understandable. In general, overriding goals should be presented early, while intermediate goals should be presented at appropriate times.

8.2.6 Feedback

The player should receive meaningful feedback at appropriate times. The player should be able to understand the consequences of their actions in the game. Feedback should be provided in a way that is consistent with the game's goal and the player's expectations. Games should provide frequent in-game feedback to help players determine their progress toward objectives and goals. The player needs feedback to understand their progress towards their goal and to know their status or score in the game. Feedback should also be provided when the player makes a mistake, and the feedback should depict the cause of the mistake so that the player can learn from it.

8.2.7 Immersion

The aspect of immersion in a game is the degree to which it allows for deep and effortless involvement. When completely immersed in a game or activity, a person experiences a loss of concern for everyday life and an altered sense of time; all attention is directed toward the activity. The investment of time and effort some games require can cause a player to be emotionally involved with the events of a game, and so can the gripping narrative and setting. Sound effects, music, visuals, and other sensory stimuli immerse the player viscerally. Immersive games use audio and narrative elements to draw players in and affect their senses.

8.2.8 Social Interaction

Games should provide opportunities for social interaction – the player should be able to interact with other players as part of the game experience. The social element may be through cooperation or competition, and the interactions may happen in the game, through chat or direct interaction, or be in-person conversations if the game is played by people in the same room. A games community, where the player can interact with other players through forums, chat, or other means, is also considered part of the social interaction element.

Social interaction is the one element of GameFlow that is not derived from Flow, and this element must be implemented with care, as it may interrupt immersion. Social interaction was added to

GameFlow because it is highly featured in the literature on user experience in games. People play games to interact with other people, and the social aspect of games is so important that people will play games they do not like or even when they do not like games at all for the social aspect alone. The negative aspect of social interaction is that it can interrupt immersion. Social interaction can potentially pull players out of their fantasy game world because real people provide a link to the real world. This negative aspect should be considered when implementing a social aspect in a game. Social interaction is a double-edged sword when looking at Flow, as it can both contribute to and interrupt Flow.

8.3 Game Reward Systems

A *game reward system* is a mechanism that provides the player with rewards for performing preferred actions. A preferred action can be finishing a level, completing a task, or performing a specific action in the game. Rewards can be in the form of points, badges, or other rewards that are not directly related to the game. Rewards can be used to motivate the player to perform the preferred actions and can be used to create a sense of achievement and progress in the game. This section describes the different types of reward systems as presented by *Wang* and *Sun* [37]. This section also includes a closer look at how reward mechanisms can facilitate and motivate learning in games, including a study on the effects of the point reward system and audio in *Kahoot!* [22]. This section concludes with a list of design considerations related to reward systems [37] that may be relevant for designing a learning game prototype.

8.3.1 Forms of Rewards

Wang and *Sun* present eight reward forms based on surveys and analyses of video games. The reward forms are described briefly in this subsection. Each description includes our own example of a game that uses the reward form.

Score System – Score systems reward players with points that add up to a score displayed to the player. The score does not typically exert a direct impact on the gameplay but can be used to compare the player's performance to other players and to motivate the player to improve their score. Score systems are often used in games where the player competes against other players, such as in competitive multiplayer games. An example of a game that uses a scoring system is the game *Tetris*, where the player gets points for removing lines. In addition, the player gets more points for removing multiple lines in one go.

Point Reward System – Point reward systems reward the player with points that result in a reward when a certain amount of points is reached. The reward can be a new weapon, a new level, or other in-game rewards. The reward is often given at the end of a level or when the player has reached a certain point threshold. In *Guild Wars*, a point reward system is present in the form of levels of the player's characters, where the character's level affects how powerful the character is and what equipment they can use.

Item granting System – In item granting systems, players are rewarded with in-game items. This is widely used in RPGs and MMORPGs and typically encourages players to explore the game world to find items. In *PlayerUnknown's Battleground (PUBG)*, the player is rewarded with items that are used to progress in the game, such as weapons, armor, and healing items.

Resources – A game may have resources that can be collected by players to be used in the game. The resources can, for example, be used to buy items, build constructions, or upgrade items or abilities in the game. In *Minecraft*, the player is rewarded with resources that can be used to build structures or craft items.

Achievement System – In achievement systems, the player is rewarded with achievements that are displayed in the game. The achievements can be related to the game or to the player's performance in the game. *Rocket League* has implemented an achievement system where the players can earn titles that are displayed under the player's name in the game. Titles can, for example, be earned by reaching certain levels or by reaching high ranks in competitive play.

Feedback Messages – Feedback messages are messages that are displayed to the player when they perform a certain action. The messages are given as instant rewards, and their value exists in the praise they evoke. *Just Dance* has implemented feedback messages displayed while the player is dancing. The messages can be "Perfect", "Good", "Ok", or "X", indicating how accurately the player performed a dance move.

Plot Animations and Pictures – Animations and Pictures may be used as rewards in games. The animations or pictures show the story progressing, show off the game world, are often visually attractive, and serve as milestones in the timeline of the game story. This reward is typically used following important events in the game and works as a reward because the player wants to advance the storyline. In *Final Fantasy VIII*, the game shows elaborate animations and music – cutscenes – when the player beats certain obstacles in the game.

Unlocking mechanisms – Unlocking mechanisms give the player access to game content. The content can, for example, be new levels or new characters. The unlocking mechanism can be used to motivate the player to explore the game and continue playing, as there is (seemingly) always new content to unlock. In the *Super Mario Bros series*, the player can unlock new levels by completing the already acquired ones or finding hidden doors that lead to optional hidden levels that many players might not find during the ordinary progression of the games.

8.3.2 Reward Mechanisms in Learning Games

Wang and *Sun* present different aspects related to reward mechanisms, some of which are relevant to learning games. The aspects are described in this subsection.

When it comes to the enjoyment of a learning game, the reward system can be a contributing factor. In a learning game, the *preferred action* of a reward mechanism should include a learning element. For example, the player may show that they have some knowledge by giving the correct answer to a question, or the player may demonstrate a skill by performing a task in the game. For the learning game to remain motivating, the knowledge or skill demonstrated must be proportional to the reward received. An excessive reward may leave the player feeling bored, while too small rewards can disappoint the player when they experience overcoming a significant challenge in the game [37].

Different types of students can be motivated by different reward mechanisms. The teachers interviewed in Chapter 7 mentioned that some students are motivated by competition, and they are likely to be motivated by competitive reward systems, such as score-based systems where they can compare their scores with others or item-granting systems where they can show off the items they have earned. If the rewards are earned by demonstrating learning, these scores or items will also be a reflection of the player's knowledge or skill, so a high-rated player should be a reflection of a competent student. Other students are likely to be motivated by cooperative reward systems, such as reward systems that reward the player for helping others learn or for learning together. Some may be motivated mainly by seeing their own advancement, and individual rewards will be fitting for them. It is important to think about who the players are and what type of players they are when designing a reward system for a learning game.

A study on the effects of the point reward system and audio in *Kahoot!* found that these game design elements had positive effects on the students' concentration, engagement, enjoyment, and motivation [22]. The research by *Wang* and *Lieberoth* was conducted by testing four different versions of *Kahoot!* in a lecture setting. The four versions of *Kahoot!* were: one with points and audio, one with points and no audio, one with audio and no points, and one with no points and no audio. The study found that the version with points and audio had the most positive effect on the students' concentration, engagement, enjoyment, and motivation. In contrast, the version with no points and no audio had the least positive effect. The study also found that the version with points and no audio had a more positive effect on engagement and motivation than the version with audio and no points. On the other hand, the version with audio and no points had a more positive effect on classroom dynamics. The results of this study are clear indications that point reward systems can have a positive effect on the enjoyment of a lecture game, and also that audio can have a positive effect on the enjoyment of a lecture game, and that the combination of the two can successfully be used in a lecture game.

8.3.3 Reward Mechanisms Design Considerations

The following design considerations are taken from the paper by *Wang* and *Sun* [37] and are relevant to game design.

Life constraint – The complexity of the game and the amount of time the target player audience has to play the game should be considered when designing a reward system. If the game is too complex, the player may not be able to learn it in the available time. If the game is too simple, the player may not be motivated to play the game.

Create Autotelic Experiences – Game reward systems give external motivation in the form of rewards, but preferably the experience is also intrinsically rewarding – i.e., autotelic. Learning and feeling like one is making real progress can be rewarding in and of itself, and encouraging this through, for example, the incentives and challenge of multi-level goals contributes to the autotelic experience.

Balance – The reward system should be balanced so the player is not rewarded too much or too little. The player should experience that the award received is proportional to the effort spent to avoid boredom and anxiety.

Uncertainty and Secrecy – In some reward systems, the reward should be designed to be unpredictable so that the player experience excitement regarding when a reward will be received next and what the reward is. This design element is not suitable for skill-correlated rewards, such as score, but can be a fun element in other reward systems, such as item granting systems.

Accumulated vs. instant feedback – The reward system can be designed to give the player instant feedback or to accumulate the rewards and give the player a reward at the end of a challenge, such as a level or multi-level task. Instant feedback is recommended for games that are usually played for a short time. For games that are played for a longer time, accumulated feedback is appropriate.

Social Purposes – The reward system can be designed to be social so that the player can share and compare rewards. Making rewards visible to other players allows for this behavior and can be a motivating factor for some players.

Physical World Activities – The reward system can be designed to be related to physical world activities. Learning is an activity that can be rewarded in learning games by rewarding the player for knowing something. This may encourage the player to study.

8.4 Summary

This chapter presented three articles on enjoyment in games, all relevant to designing an interesting learning game to enhance the learning experience. The articles mention challenge as an important aspect of an enjoyable game. A challenge needs to be sufficiently challenging, and the challenge should match the player's skills. There are many design decisions to consider when it comes to rewarding a completed challenge, but one of the most important aspects is that the reward should be proportional to the effort spent. For learning games, this means it is beneficial to create challenges that require learning and reward the player for learning. Creating a fantasy in a learning game can make the learning experience fun and help motivate students to learn. Presenting the fantasy through sensory stimuli, such as music and visuals, can make the player immersed in the learning experience. Feedback and control are important for the overall playability of the game.

9 | Theories of Learning in Games

To analyze the learning opportunity for a game concept and optimize a game concept for learning, one must understand how learning works in games. This chapter presents some traditional theories surrounding learning that are deemed especially relevant for learning games. The chapter also looks at a collection of techniques gathered by *James Paul Gee* [38] originating in the practice of game design that can be used to make players learn in games. Finally, the *LEAGUE framework* by *Tahir* and *Wang* [39] is described. The LEAGUE framework is an extensive framework for analyzing learning games, focusing on producing holistic perspectives.

9.1 Traditional Learning Theories

The theories for how learning works in general are a good starting point for theories within the field of *game-based learning*. *Behaviorism*, *cognitivism*, *constructivism*, and *humanism* are especially interesting to *game-based learning* [23] and will be briefly introduced in this section.

9.1.1 Behaviorism

Behaviorism is a theory from the early 20th century that describes the learning process [23]. It reduces the relevance of introspective mechanisms and focuses on the relationship between the stimuli an actor experiences and the observable actions of the actor that follows – *the behavior*. It can be said that the mind is treated as a *black box* where only input and output are of interest [40]. The theory further states that learning is a passive activity and that guided learning – teaching – happens through the reinforcement of good behavior and punishment of bad behavior [40].

The model has strengths and weaknesses but has been phased out in favor of other learning theories over time [23]. The model of learning that the theory provides can easily be tested experimentally, which is a strength [23]. On the other hand, the theory can not explain how some actors are able to perform well in unexpected or novel situations or how to teach for such situations [23].

9.1.2 Cognitivism

Cognitivism is a competing theory for learning that rejects the assertion that the mind should be viewed as a *black box* and takes an interest in the inner mental processes during learning [40]. Studies in cognitivism are often related to information processing and the manifestation of acquired knowledge, for example, through concepts such as memory, organization, and neurological connections [40]. Learning different tasks, like talking or spelling, requires different mental processes, and findings about these mental processes help educators design and enhance learning activities [40].

9.1.3 Constructivism

Constructivism is a learning theory characterized by the belief that learning outcomes and personal development are absorbed by a learner through the incorporation of knowledge into the preexisting *mental model* of the learner [23]. This means that the state of the mental model of each learner is fundamentally relevant and that the role of the educator is to help the learners generate and incorporate their own understanding of the learning content in question [40]. It also means that the level of cognition changes through knowledge acquisition, meaning that education or educators can help promote cognitive development [41]. Common elements of constructivist learning activities are active engagement, inquiry, problem-solving, and collaboration [40].

Social constructivism is an extension of constructivism that adds that "understanding, significance, and meaning are developed in coordination with other human beings" and that "language is the most essential system through which humans construct reality" [41]. A consequence of this is the fact that meaningful learning can only take place in social activities [41]. The **Zone of proximal development** (ZPD) is defined to be the area between the most advanced problem an individual is able to understand and solve alone – the actual level of cognition – and the most advanced problem an individual is able to understand and solve with support, such as a teacher or capable peers [41]. It is suggested that the level of one's ability creeps forward while being in the ZPD, i.e., trying to solve a problem one would not be able to do alone [41].

9.1.4 Humanism

Humanism is an approach to learning where the focus is on the learner. While behaviorism and cognitivism adopt a theory on learning that causes focus to land on the teaching process, constructivism adopts a theory that implies that the individual is important for the reception of knowledge. Humanism takes this aspect from constructivism even further and makes it a core theory of the philosophy. Supporters of humanism believe each learner has a natural and intrinsic desire to learn, and through this desire, learning is optimized. An example of a hypothesis that becomes interesting within this learning paradigm is that learner agency – control over learning techniques and learning content – contributes to motivation and self-actualization [23].

There exist prevalent points of criticism towards humanism. Some argue that its view of human nature – stating that every learner has the desire to learn – lacks empirical footing, is subjective and naive [23]. Others argue that humanism only addresses "healthy" learners [23].

9.2 Learning by Design

James Paul Gee argues that game designers must have developed several techniques to cause players to learn how to play games without complaint [38]. If learning how to play a game is too boring, it would not do well financially, as players, who play games for entertainment, would simply drop it. *Gee* thinks these techniques can be utilized to enhance school and workplace learning, either through games or otherwise. In his article "Learning by Design: good video games as learning machines", *Gee* presents several such techniques organized into the categories of *Empowered Learners*, *Problem Solving*, and *Understanding*. This section summarizes these techniques.

9.2.1 Empowering Learners

Empowerment in learning means that the learner feels like they are in control of their own actions and can make meaningful choices. *Gee* identified that this can be achieved through the following techniques:

Co-design – The player must feel like an active force that contributes to how the experience plays out. The experience should be more than just what the designer has designed. Letting learners affect the results of learning sessions, like the learning outcome or other artifacts, are ways to achieve this in education.

Customize – Different people work better with different styles of learning. Learning situations should respect and facilitate different learning styles and encourage experimentation around learning styles.

Identity – Letting players take on new identities that they find interesting can get them invested and committed to the activity, for example, a scientific mastermind or a new role at work. One way to achieve this is to design such intriguing characters or roles and include them in the activity. Another way to establish a character the player is invested in is to present a mostly empty character whose traits are determined by the player over time.

Manipulation and Distributed Knowledge – Fine-grained and intricate manipulation of objects from afar makes them feel like extensions of the body and mind. Extending the area of effectiveness of humans in this way is empowering. In addition, these controllable objects, or tools, can be said to have the ability to contain knowledge. The player must not necessarily know how the limbs should move during climbing to get a character to climb in a game. The character in the game can "contain" this knowledge in its animation system, moving automatically as the player orders the character to climb. Realizing that "smart tools" can take over such responsibility can make tools more flexible in designing experiences, and *Gee* thinks it gives a healthy understanding of what tools are.

9.2.2 Problem Solving

Similar to players in games, learners in learning situations are often tasked with solving problems. *Gee* has identified seven techniques from game design that can be utilized to make problem solving in learning more interesting and engaging. These techniques are:

Well-ordered Problems – The order of problems a learner faces is important. If a learner is first presented with a problem that is too open or too complex, they might create creative hypotheses that are not general and are not good solutions for future problems. The order and content of problems a learner is tasked with solving should be designed to make the learner take helpful conclusions so that they are left with general knowledge, meaning they know how to proceed during the next problem, etc. The people who are already adept in a field are the best suited to find such abstractions and insights.

Pleasantly Frustrating – A learner can lose motivation both when a challenge feels impossible and when it is too easy, i.e., when they are not learning. Tasks in learning activities should be on the rim of the learner's abilities, and even if the learner fails, they should see the way forward. Games utilize many techniques to achieve this, like adapting difficulty or communicating the difficulty of a specific challenge and letting the player choose when to tackle it.

Cycles of Expertise – Expertise results from a continuous cycle of practice and rethinking. Learners will practice the skills they have until proficiency, then utilize the skills until they fail, which elicits a reevaluation of strategy and a new cycle of practice towards new skills. In fact, only by being proficient in the skills one possesses and understanding them well can one realize and trust that the skill itself is flawed instead of the application. Games utilize this cycle to great effect through levels and bosses. Going from one level to the next is often understood to mean that the challenge will change in some fundamental way, and bosses at the end of levels are often a more difficult incarnation of the same challenges the player is already used to.

Information "On Demand" and "Just in Time" – Verbal information is not easily understood out of context. Without context, one can not supplement the theoretical definitions of the words or how they apply to the situation in question to understand them. Presenting verbal information "just in time", when it can be put to use, and "on demand", when it is needed, makes it more helpful and influential. Games can be programmed to automatically give specific pieces of information in different situations based on metrics and events, and can make information readily available when needed, for example, through a digital manual or encyclopedia.

Fish Tanks – It is easier to learn something if presented in a simplified environment where unnecessary complexities are removed, and the focus lies on the aspects and interactions essential for the subject in question. The concept of this simplified and purpose-designed environment takes its name from fish tanks, which are simplified ecosystems. In video games, it is often easy for designers to turn off game mechanics, creating Fish Tanks for learning specific skills. In traditional teaching, learners often learn about subjects without the subject's context or environment being present.

Sandboxes – While Fish Tanks create suitable learning environments by reducing complexity, Sandboxes are designed experiences where learning and experimentation is encouraged by reducing risks and dangers. Pressure and fear of failure can discourage action and learning. Games achieve Sandboxes by making experiences much like the broader game, but where failure is impossible or happens less violently.

Skills as Strategies – People do not like practicing a skill repeatedly out of context. When a learner see that a skill helps achieve some goal that they want to accomplish, they learn better. Games are good at presenting skills as tools or techniques and as part of more extensive strategies. Tools and techniques can often be used together with other skills to advance game goals.

9.2.3 Understanding

Understanding is the ability to use knowledge in practice, and it goes beyond just knowing the definition of a concept. Understanding is also the ability to see how knowledge is related to other knowledge and the ability to see how knowledge fits in a bigger picture. *Gee* presents two techniques for how to teach understanding:

System Thinking – To fully understand something, the learner should also understand how it fits in the larger picture. Memorizing a definition of a concept is not sufficient. The learner must be able to see how a concept is related to other concepts and how it is used in practice to be able to apply the knowledge in practical situations. Learning activities should be designed to help learners understand the whole system of what is being studied.

Meaning as Action Image – People do not think through general definitions or logical principles, but rather through experiences and imaginative reconstructions of their own experiences. Learning games should be designed to make the meaning of words and concepts clear through experiences. The learner should be able to see the meaning of a concept in action, so they can use this experience as a basis for understanding the concept.

9.3 The LEAGUE framework

With a comprehensive framework for evaluating learning games – the LEAGUE framework – *Tahir* and *Wang* address the discernible problem of lack of holistic perspective in research into the evaluation of learning games [39]. The framework gives a detailed picture of game-based learning that can help designers, developers, evaluators, and researchers alike.

Tahir and *Wang* argue that there is not a lack of studies in the field of GBL evaluation, but exhibited methodology is problematic for supporting a holistic view [39]. They list four identified problems: (1) Evaluation frameworks and studies focus on only one aspect of GBL each, (2) no clear pattern emerges because of the high number and diversity of different elements used for evaluation, (3) GBL aspects are not contextualized in relation to other GBL aspects, so hierarchical decomposition and scope are unclear, (4) there exists inconsistency in definitions, usage, scope, and terminology of evaluation elements [39]. An example of the third problem is *interactivity*, which some studies present as a *core dimension*, while others include it as a *factor* in the usability dimension [39].

Tahir and *Wang* attempt to solve the identified problems with the LEAGUE framework, presented in their study "Codifying Game-Based Learning: The LEAGUE framework for Evaluation" [39]. The study is a direct data analysis of literature regarding the evaluation of GBL from a systemic literature review. Elements used in GBL evaluation were systematically reviewed and organized into 6 *core dimensions*, 22 *factors*, and 74 *sub-factors* based on "scope, frequency of occurrence, relationship between codes, underlying meaning across codes and mapping to existing theoretical frameworks and constructs defined by researchers in the domain of GBL".

Figure 9.1: *Core dimensions*, *factors*, and *sub-factors* of evaluation of GBL as specified in the *LEAGUE framework* [39].

Below are descriptions of the meaning of the 6 identified *core dimensions*.

Learning – The learning dimension is concerned with the gameplay's effect on learning: The characteristics of the game that promote and facilitate learning, the characteristics of the gameplay (activity) that concerns learning, the learning achieved by players, etc.

Environment – The environment dimension is concerned with the context of the learning activity, the physical environment of the learner, and the technical accessibility of the game. The context is the setting of the learning activity, and the physical environment is the physical space where the learning activity takes place. Technical accessibility is related to how easy it is for the learner to access the game and the technical requirements of the game.

Affective Reactions – The affective reactions dimension is concerned with the learner's emotional reactions to the learning activity. A learning game can trigger a set of emotions, attitudes, and feelings in the learner, which may result in the experience of enjoyment, engagement, motivation, or flow state.

Game Factors – The game factors dimension is concerned with the game design. It is related to the game mechanics, the game rules, the game aesthetics, the game narrative, and the gameplay.

Usability – The usability dimension is concerned with the game's ease of use. How easy a game is to use depends on how easy the interface is to understand and use, and how easy the game is to learn. Considering a game's comfort and acceptability to its user is also relevant.

Us**E**r – The user dimension is concerned with the learner. A target user group should be identified when designing a learning game, and their needs and attributes should be considered. A learning game should suit the learners' cognitive development level and their psychosocial needs.

Tahir and *Wang* also ties the concept of *metrics* to the LEAGUE framework [39]. *Metrics* are measures of how much the utilization of learning games exhibits specific *factors* and *sub-factors*. The numerous *metrics* encountered in the systematic literature review were categorized into five categories: (1) scores, (2) time, (3) occurrences, (4) rating, and (5) reviews/responses/opinions.

The LEAGUE framework is a hierarchical structuring of concepts used in GBL evaluation into *core dimensions*, *factors*, *sub-factors*, as well as *metrics*. *Tahir* and *Wang* highlight some areas in which the framework can be utilized, including: Formulating research objectives relating to the evaluation of GBL with the framework as a connection to the holistic view of the field, and creating an evaluation plan and data collection procedure [39].

9.4 Summary

Several perspectives on learning in games have been looked at in this chapter. Traditional learning theories are based on different core assumptions and have very different ways of framing learning, the learning process, and how to cause it. *Gee* formalizes techniques developed and used by game designers to cause learning without complaint. LEAGUE framework aims to introduce terminology to make a holistic view of the field of game-based learning easier and make analyses within it more comparable.

10 | Deep Processing

To answer the research questions of this project (see Chapter 3), it is important to understand the concepts of *deep processing* and *surface processing*, the *learning approach model*, and the surrounding research field. This chapter defines deep processing and other related concepts, presents the state of the field, and introduces relevant methods found in the preliminary study. This chapter also presents one specific method for achieving deep processing relevant to this project – constructing *argument graphs*.

10.1 Deep Approaches to Learning and Deep Processing

The Norwegian Directorate for Education and Training defines deep processing to be learning in which lasting understanding is developed of concepts, methods, and the connections between them, and the ability to utilize this understanding in new situations [1]. Synonymous terms are *deep-level processing* or *deep learning* [42]. It is often contrasted with *surface processing*, also called *surface-level processing* or *surface learning*, which is characterized by short-lived memorization of the medium of the learning content [42], e.g., a text, without understanding it. One example of possible results of surface processing is being left with the ability to recite a definition of a concept, while not grasping the properties the definition is trying to attribute to the concept in question.

A *deep approach to learning* is when a learner is motivated to achieve deep processing because of intrinsic motivation for understanding the learning content in question or because they see the apparent usefulness of the results of deep processing [43]. Analogous to the relationship between deep processing and surface processing, a *surface approach to learning* is when a learner is motivated to use surface processing because of intrinsic motivation or because they see the apparent usefulness of the results of surface processing [43]. Depending on the methods of evaluation used in schools, surface processing might be a way of achieving a good result in a more time-efficient manner in the short term [44].

10.2 Origins of Field

John B. Biggs developed the model of deep and surface approaches to learning in the late 70s and 80s [44, 45]. *Biggs* built upon similar ideas that were present in other studies at the time [44], including the findings about deep-level processing and surface-level processing of *Marton* and *Säljö* [46, 47], and *Entwistle et al.* work on gathering research on learning approaches and finding promising concepts that could define the field [48].

Biggs states that a deep approach to learning is desirable. A surface approach encourages using low-level *learning "verbs"*, which leaves the student with recitation skills only. Although appropriate for some learning outcomes, such as remembering mathematical formulas, a deep approach to learning is better because it encourages the use of low and high-level learning "verbs", such as *hypothesizing* and *arguing*, as appropriate, which is necessary for a lot of learning outcomes [49].

10.3 State of Field

Much effort has been dedicated to applying the model in teaching and empirically showing the connection between deep processing and higher learning outcome [42, 45]. However, the results are inconsistent and ambiguous; the suggested relation only holds in some studies [42], and the results are hard to compare and aggregate because the terminology and language surrounding the model vary significantly [42, 45]. *Howie* and *Bagnall* argue that the contemporary pressures of the educational research field when the model was created have led to the stagnation of active development of the *learning approach model* even though needed [45]. *Dinsmore* and *Alexander* present a non-exhaustive list of **four** problematic areas to the research of the *learning approach model* that can account for the inconsistent results: (1) *Conceptualization*, (2) *operationalization*, (3) *contextualization*, and (4) *model specification* [42]. The concerns of *Dinsmore* and *Alexander* related to *conceptualization* and *operationalization* will be described further.

Conceptualization is the elaboration and specification of concepts. Conceptualization is the foundation for how a study is framed and for its meaning. Missing, implied, ambiguous, or differing conceptualization of terms could therefore contribute to the discrepancies in results surrounding deep processing, as it has done in motivation and strategic thinking literature [42].

Operationalization is the determination of measuring methodology for phenomena that are not directly measurable. In learning approach literature, as in strategic process literature, there is a high reliance on *self-report questionnaires*, which can be problematic because it requires meta-meta-cognition – thinking about one's own thinking – which is susceptible to bias [42]. *Dinsmore* and *Alexander* present **six** *types of measures* that they found in deep processing literature: (1) *By self-report questionnaires*, (2) *by condition* – by constructing a situation where the phenomenon is a precondition for certain outcomes, (3) *by a physiological response*, like eye movement, (4) *by coding scheme* – a systematic approach to ascertain a phenomenon from qualitative data gathered during or after the phenomenon, (5) *by outcome* – by measuring and analyzing some (learning) outcome of the phenomenon, (6) *none* [42]. Any measure is only as good as the validity of the inference from measurement to the concept being measured, and so for a measure to be a good operationalization of the concepts, this validity must be addressed and proven [42].

10.4 Constructing Argument Graphs for Deep Processing

Constructing *argument graphs* is one proposed method that can help students use higher-order thinking skills and achieve deep processing [50, 51]. Some different versions of argument graphs exist, with different rules and conventions [51, 52]. However, the consensus is that an argument graph is a visual representation of the structure of argumentation that typically takes the form of a directed acyclic graph, where the nodes are arguments and the edges show the relationship between the node arguments [50, 51]. An example of an argument graph is shown in Figure 10.1. The nodes of the graph are arguments that are linked together by arrows. The arrows are either *supportive* (+) or *critical* (−). A *supportive* arrow indicates that the argument at the tail-end of the arrow supports the argument at the head. In contrast, a *critical* arrow indicates that the argument at the tail contradicts the argument at the head [51].

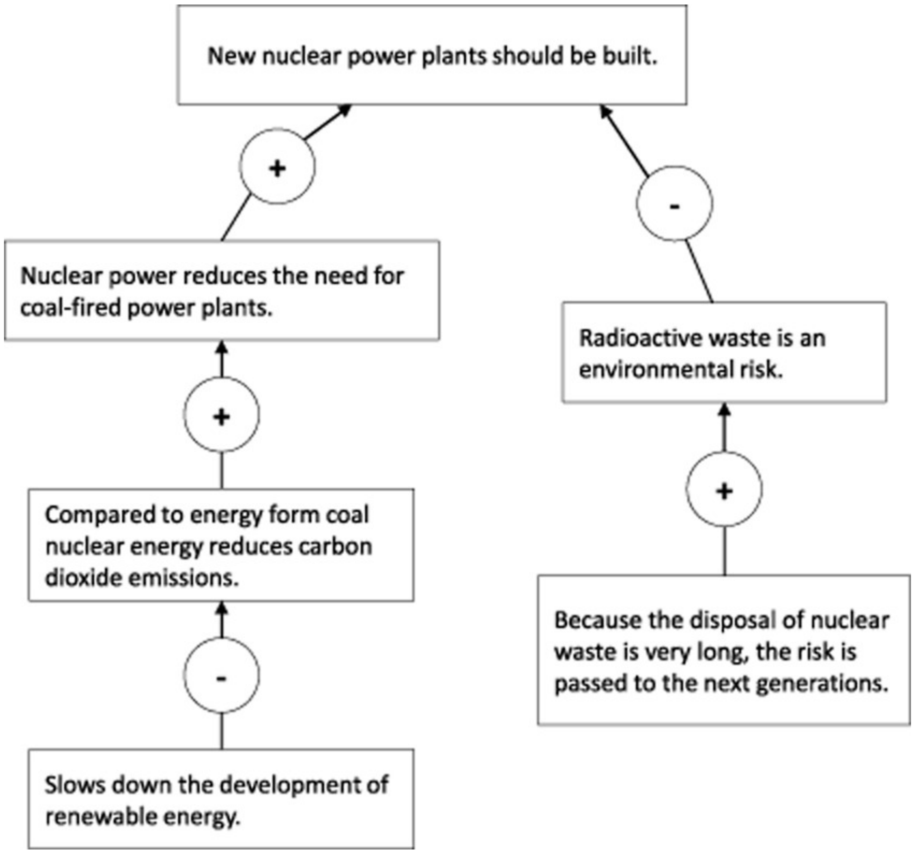

Figure 10.1: An example of an argument graph from the study by *Kiili* [51].

A study published by *Kili* in 2013 found that by constructing argument graphs, students could explicate their synthesizing processes more effectively than by taking notes [51]. The study was conducted on upper secondary school students in Finland. The students worked in pairs and were divided into an argument graph group and a note-taking group. All pairs were tasked with writing an essay, but the argument graph group was asked to create an argument graph before writing the essay, while the note-taking group was told to take notes. The note-taking group functioned as a control group. The quality of the essays of pairs in the different groups was then compared to see if there was a difference in quality. This study's findings indicated that using an argument graph was particularly beneficial for students in terms of fostering their ability to contemplate the connections between arguments and express these connections explicitly. The research also found that with argument graphs, teachers can better support students' post-reading activities, such as source-based argumentative writing.

10.5 Operationalization of Approaches to Learning

A version of the *Learning Process Questionnaire* (LPQ), adapted by *Dan Murphy* into a 16-item self-report questionnaire [53], is used in this project to measure the predisposition of students to utilize the deep and surface approaches to learning in a general school context, thus serving as the operationalization of said concept. The original LPQ by *John Biggs* encompasses 36 questions and is regarded as being too long [54]. *Dan Murphy's* questionnaire is more appropriate in length. In addition, it includes statements to be rated that fit well with the specifics of the conceptualization of deep processing in this project, like "I like to do enough work on a topic so that I can form my own conclusions before I am satisfied." and "I prefer subjects in which I have to learn just facts to ones which require a lot of reading and understanding material."

10.6 Summary

This chapter presents concepts and methods relevant to the project from, and challenges facing, the deep processing field of research. The concepts of deep and surface processing were defined through characteristics of the learning outcomes it causes, and deep and surface approaches to learning were defined through motivation during learning. The state of the research field was summarized through a look at its origins and recent challenges, especially with a focus on *Dinsmore* and *Alexander*'s concerns regarding conceptualization and operationalization. Researchers must pay attention to these areas if their studies are to be properly contextualized in the field and thereby useful. *Dan Murphy's* adaptation of the LPQ was presented as an operationalization of the concept of a student's usual approach to learning, deep or surface.

11 | Relevant Technology

This chapter will elaborate on relevant technologies that can be used when developing multiplayer games. The chapter is divided into two sections: **Architecture for Distributed Software**, which looks at how applications can be structured to be distributed, and **Platforms and Compilation Targets**, which describes some platforms and compilation targets that are available for independent game developers and looks at the use cases, advantages and disadvantages related to these.

11.1 Architecture for Distributed Software

There are two main ways to structure distributed software applications: *client-server* and *peer-to-peer* (P2P) [55]. With the *client-server* model, one or more computers in a network are explicitly dedicated to serving – *servers* – the needs of the other computers – *clients* [55]. In P2P, all computers are *peers* – of the same ability – and can both consume and serve [55].

The two models have characteristics that make them more or less suitable in different situations. P2P configurations can, in theory, be more *fault-tolerant*, *scalable*, and *performant*, as they have fewer *single points of failure*, and more *redundancy* and *parallelism* [56]. In P2P configurations, peers contribute a bit of resource, e.g., network bandwidth or processing power, to the network, and dedicated central resources or coordination is not needed. In client-server configurations, servers need to be maintained that supply these resources. It therefore varies which is more fit based on the willingness and ability of peers to contribute resources and the cost of maintaining central resources [55]. The interactions between computers in a client-server configuration are much simpler than those in P2P since the responsibilities are clear and distinct. P2P, on the other hand, needs more advanced discovery and searching functionality, routing, and load balancing [56]. In addition, peers have more responsibilities than consumers in client-server configurations – a bigger attack surface – making it somewhat harder to protect against malicious actors. Security is a challenging area for P2P [56, 57].

11.2 Platforms and Compilation Targets

Independent developers can develop applications for many platforms and compilation targets. The compilation targets have different advantages, disadvantages, and use cases.

Platform owners often distribute *software development kits* (SDKs) to allow independent developers to create applications for their platforms [58, p. 143]. These bundles make it easier to interact with the platform functionality, and the goal is to enhance app developer productivity on the platform [58, p. 143]; developing an application to be compatible with a platform through an SDK will often mean that the application only works for the platform in question, and is called a *native application* [59]. The drawbacks of *native applications* are that the platform's user base determines the application's availability, and it is expensive to switch platforms [58, 59]; known as a so-called *lock-in* [58].

One way developers can create an application that works on many platforms is to use *runtime environments*, such as *.NET* and the *Java virtual machine* (JVM) [60]. Instead of developing many different applications, one for each platform, runtime environments offer the ability to develop for just one compilation target that works on many platforms [60]. A number of drivers and applications act as the interface between the compilation target and a number of different platforms. The functionality that runtime environments make available to applications created for them is usually quite basic and low-level [60]; the more advanced functionality that some platforms support is usually not supported by all platforms, and since the compilation target should work on many platforms, this functionality cannot be included easily in runtime environments.

The *web* is a runtime environment that offers more advanced functionality, like background processing capabilities and location information, and the web, uniquely, is maintained in a very distributed and collaborative manner [61]. International consortiums and organizations like World Wide Web Consortium (W3C), Ecma International, and International Organization for Standardization (ISO) develop and maintain standards that specify the runtime environment which the browsers implement [62]. The massive audience and market available to developers through the web, and the distributed competitive environment, means that a lot of resources are spent to make every part of the ecosystem – e.g., browsers and content delivery networks – performant and effective, trying to edge out an advantage over competitors on the web [61]. It has also given rise to several varied high-quality frameworks and libraries used to develop for the web, giving rise to customizability based on needs. However, the web as a platform developed alongside and in concert with the concept of a website; the efficiencies, complexities, and design decisions of the web can get in the way when creating applications that do not conform to the website conventions [61].

Game engines are another type of high-level runtime environments that spend the resources necessary to make even advanced functionality useful for game development available for applications developed for their compilation target [63]. These features, for example, online multiplayer, artificial intelligence agents, and life-like 3D graphics, take considerable effort to develop and maintain for all the supported platforms [63]. Examples of game engines are Unity and Godot. Applications developed with game engines are usually very computationally intensive and are shipped with gigabytes of textures and assets; because of this, space and time overhead that would be unacceptable for websites and other applications is trivial compared to other parts of games and game distributions. For example, it's recommended that a gamer dedicate 50 GB of space on their computer to Sims 4, a popular game by Electronic Arts [64]. As a result, the size and performance of small applications are not usually optimized for in game engines; even empty projects can result in executables hundreds of megabytes big when compiled.

11.3 Summary

There are multiple ways to structure distributed software applications and multiple platforms and compilation targets to use for game development. The two main ways to structure distributed software applications are P2P and client-server. In P2P configurations, peers contribute resources. In client-server configurations, servers contribute resources and serve the needs of the other computers. Independent developers can choose between many platforms and compilation targets for game development. The web is a runtime environment that offers more advanced functionality, like background processing capabilities and location information, and the web is maintained in a distributed and collaborative manner. Game engines are high-level runtime environments suitable for complex game development.

Part III

Game Concept Selection

This part describes the deliberation around game concepts that could be used in potential research, and the selection of the most fitting one. Seven game concepts were conjured up, and their research potential and practical feasibility were compared to select the one to become the basis of this master's project, *Collective Reasoning*. This part is included to build confidence in the selected game concept's merit as the research subject. This work was performed as part of the specialization project [2] before the master project started, and the content is primarily the same. However, the selection process in Chapter 14 has been reworked to summarize the detailed selection process of the specialization project. During the specialization project, the scope of the research was not limited to deep processing within game-based learning – in fact, the scope reduction is a consequence of this selection process – so the potential research of the game concepts aims at several different fields and concepts.

12 | Research Potential

It was important to recognize possible research topics within game-based learning and consider their research potentials to ensure that the game concept chosen to pursue in the master's project was relevant for research within the field. This chapter presents research topics, their primary field of contribution, and a discussion of the possibility of not generating contributions. Each presented research topic is relevant to at least one of the proposed game concepts; the game concepts are presented later.

12.1 Potential Research Topics

The process of recognizing potential research topics resulted in 13 different topics presented in Table 12.1. The potential research topics were conceived to be possible avenues for generating new knowledge from the game concepts without any other requirements, meaning that we did not, for example, require the topics to be within a specific field or subfield. Each research topic is presented with an ID – in the format RPx – and a title, which are used to refer to the topics in later chapters. The research topics are described briefly, and the descriptions include examples of questions within the topic we believe can be further explored.

Table 12.1: Potential research topics.

RP1	**Time pressure**
Different students might have different reactions when faced with time pressure. Does time pressure affect cooperation and learning outcomes?	
RP2	**Differing student roles and role distribution**
Students might experience different learning outcomes based on the role they play in a game. With the rise of personal devices and asymmetric games, different player roles can be present in the same game, and the topic can be analyzed. The process of assigning roles can also be explored. Are students more engaged and learn more in roles that fit their personality? Do students learn more if they get to choose the role they play rather than if they are randomly assigned?	

Continued on next page

Table 12.1: Potential research topics. (Continued)

RP3	**Individualized reward mechanisms**
A game can employ a plethora of different reward mechanisms to make the game enjoyable, which are utilized in specific and different circumstances. It is interesting to analyze how student bodies react to such a situation. A score reward system might target well-performing individuals, while animations and sensory stimuli target students who lag behind. It could happen that a student who is usually well-performing is not "represented" or does not accept the score reward and would instead want the reward for a worse performance. How well do students accept the rewards they get at their level of play? What is a typical distribution of acceptance of different reward mechanisms in a classroom setting? Does this acceptance of rewards change for an individual based on social context? Are individuals able to predict what reward mechanisms they will enjoy?	
RP4	**Gradually revealing question**
Revealing a question or hints over time while the students are pondering might enhance learning by forcing participants to give a question serious effort even when initially very difficult. The difficulty of a question can be reduced after the player answers it wrongly, which could motivate the player to try again. This engagement might mean that the participants gain a bigger picture of the subject and surrounding context than if the answer was revealed after only one step of information reveal – the original question. Does this technique improve learning?	
RP5	**Distributed evaluation processes**
An evaluation process distributed among students has many potential ways of affecting learning outcomes. In addition to allowing for the quiz and questions to be less leading by allowing for text-field answers, it makes the students reflect on the subject of the question additional times, and even maybe with new perspectives and ideas from other students. Does a distributed evaluation process with students enhance learning? Relying on students to perform a crucial step of the game is risky, as one must be careful not to let the students game the system. The process will also inevitably introduce complexity and extra steps in the game loop. How manageable is the implementation of such distributed evaluation processes?	
RP6	**Deep processing**
Can the need for the intent or motivation of a deep approach to learning be circumvented by instead motivating the students to utilize deep processing through the short-term rewards of game reward systems and making the desired techniques easy to perform with software? What activities within deep processing are most compatible with games, and which activities within games are most compatible with deep processing?	
RP7	**Programming collaboration**
Collaboration in programming tasks at school can increase the resources available for students to create programs they can be proud of. In addition, both collaboration and programming are part of the new national curriculum in Norway. Programming is, however, a recent addition, and there is bound to be a skill gap between the especially interested students and students who learn it for the first time in school. Is this discrepancy in programming skills among students in the current Norwegian school system relevant, and is it too big? Are there other circumstances that make programming especially hard to collaborate on than other parts of the curricula?	

Continued on next page

Table 12.1: Potential research topics. (Continued)

<table>
<tr><td>RP8</td><td>The escape room trope</td></tr>
<tr><td colspan="2">Progression reward mechanisms can generate motivation for progression through a game. If progression is associated with learning, this also causes motivation for learning from the game. It can be interesting to concretize the escape room trope as a type of progression reward mechanism with strong fantasy elements. Is this trope interesting to students? Does the trope efficiently communicate the objectives of games that utilize it?</td></tr>
<tr><td>RP9</td><td>Acceptance of group-wide answer</td></tr>
<tr><td colspan="2">A class of students will likely not be in complete agreement during a process of selecting a group-wide answer. Some students will be represented, while others will not. How does this affect how individuals experience rewards given to the players or class based on the performance of the class-wide answer? Can the acceptance of the group-wide answer be increased by utilizing different answer selection processes?</td></tr>
<tr><td>RP10</td><td>Engagement of misrepresented voters</td></tr>
<tr><td colspan="2">Some game mechanisms construct group-wide answers from the contributions of many players, and some players might end up repeatedly not being represented by this answer – misrepresented voters. Does increasing the influence of or rewards experiences by misrepresented voters increase engagement and learning outcomes? Is there even any discernable problem with historically misrepresented voters in collaborative quiz games? Does an increase in voting power of historically misrepresented voters change the class environment to incentivize helping the lowest performing individuals learn more?</td></tr>
<tr><td>RP11</td><td>Exposure to surrounding facts and details</td></tr>
<tr><td colspan="2">Typical quiz-like learning games often reveal the correct answer after the player has given an answer. In this type of game the learning outcome is limited to the correct answers to specific questions. By revealing information linked to the topic of the question beyond just the correct answer the possible learning outcome of the game increases. Does revealing details beyond just the correct answer increase learning outcome? Are students interested in details beyond the correct answer?</td></tr>
<tr><td>RP12</td><td>GameFlow in groups with asymmetric gameplay</td></tr>
<tr><td colspan="2">GameFlow in collaborative games can be hard to achieve because associations with other player and the medium they interact through can remind players of reality and pull them out of Flow [35]. How can collaborative games be design to achieved GameFlow?</td></tr>
<tr><td>RP13</td><td>Secondary learning effect of abstract concepts</td></tr>
<tr><td colspan="2">With strong intrinsic fantasy elements in games, learning often does not take center stage because it is difficult to design games where the goal of learning can be combined with the goal in the fantasy, which is inherently restricted. Therefore, it is important to understand the effectiveness and measurability of secondary learning effects in games to understand the applicability of intrinsic fantasies in learning games. Concepts attempted to be taught passively in games where the learning is not a primary goal or focus can be varying levels of abstract. Are games created with secondary learning effects in mind better at teaching concrete facts or abstract concepts?</td></tr>
</table>

12.2 Field of Contribution

Because of the way the potential research topics were found, they are not exhaustive, and the field of research they primarily contribute to varies. A categorization of the research topics into their primary field of research, including subfield or topic where it is relevant, can be found in Table 12.2. The definition of the field of pedagogy used here is the theory of teaching and learning, and the field of game design is the theory of designing games to fit goals. All contributions to game design are useful in the field of applied game technology.

Table 12.2: The principal fields of potential research topics.

ID	Title	Field	Subfield or topic
RP1	Time pressure	Pedagogy	-
RP2	Differing student roles and role distribution	Game design	Player types
RP3	Individualized reward mechanisms	Game design	Reward systems
RP4	Gradually revealing question	Pedagogy	-
RP5	Distributed evaluation processes	Game design	Game-based learning
RP6	Deep processing	Pedagogy	Deep processing
RP7	Programming collaboration	Pedagogy	Teaching programming
RP8	The escape room trope	Game design	Reward systems / fantasy
RP9	Acceptance of group-wide answer	Game design	-
RP10	Engagement of misrepresented voters	Game design	-
RP11	Exposure to surrounding facts and details	Pedagogy	-
RP12	GameFlow in groups with asymmetric gameplay	Game design	GameFlow
RP13	Secondary learning effect of abstract concepts	Game design	Game-based learning

12.3 Possibility of No Contribution

The possibility that the research project has no conclusions or contributions to research should be minimized. Some examples of mechanisms that can cause this are that the phenomenon to be analyzed is not observed or that insufficient data prevent researchers from accepting or rejecting a hypothesis with sufficient confidence. The formulation of a hypothesis can contribute to how prone a research project is to be unable to produce findings. All the potential research topics presented in Section 12.1 are reasonably abstract, so there are likely hypotheses inside each that both suffer from and do not suffer from such unfortunate potential. RP6 and RP12 cover phenomena that are not trivial to reproduce, namely deep processing and GameFlow; any hypotheses within these topics that do not involve the reproducibility of these phenomena rely on the phenomenon in question being observed, which is risky. That said, no potential research topic is judged to increase the possibility of no contribution to a degree where it warrants taking this into account in the game concept selection process.

12.4 Summary

This chapter presented 13 potential research topics relevant to the game concepts in the next chapter. Each research topic is either in the field of game design or pedagogy, and it should be possible to create hypotheses without the risk of no contribution within each topic. The next chapter presents the game concepts that can be used to perform research on these topics.

13 | Game Concepts

In this chapter, the proposed game concepts are presented. There are seven in total, and each game concept includes a description and a table with relevant potential research topics. In addition, some concept descriptions include variations or opportunities to provide possible future directions for the game concept in question.

13.1 Category Schooling

Category Schooling is a game where a group of students cooperates to classify answers into categories. One of the most simple classification problems is the classification between right and wrong answers. However, other classification problems could be: Sorting species into taxonomical kingdoms in biology, sorting words into lexical categories (verbs, nouns, etc.) in language study, or sorting cities into countries. The learning content in the game is flexible since the classification problem can be customized. The classification skill is foundational for gameplay, so the game features a primary learning effect.

Another role that can be included depending on the categorization problem is a saboteur. The challenge for the saboteur is to make the categorizing group commit as many errors as possible by creating additional answers for the group to categorize. This introduces competitive elements into the gameplay. One strategy saboteurs can use is to make answers that seemingly fall into one category but actually belong to another. Examples of this are the taxonomical kingdom of corals, which, to the surprise of some, is the animal kingdom, not the plant or fungi kingdoms, or the fact that the Caspian Sea and the Dead Sea are not seas but lakes.

Variations

Conveyor belt vs. board – The answers can either float by, like on a conveyor belt, or be presented many at once on a board. In the case where they float by, the group has until the answer has moved across the screen to figure out which category it belongs to. In the case where many answers are presented at a time, the group has a specific amount of time to classify all answers.

Ultra-long duration – The game is likely to be played in short sessions where the time allocated to solve one case is usually relatively short. However, nothing stops the game from working on time scales measured in minutes, hours, or even days instead of seconds. In some subjects, like math, a problem can often be solved in many different ways, with different balances between upfront work to generate the method and per-case work. A group can be incentivized to really sit down with the problem and develop tools and techniques – scaffolding – to easily solve each case if there is a sizable amount of cases, but still be left with the option of brute forcing each case with more primitive techniques.

Category experts – Instead of leaving each student with total freedom to move all cases into all categories, the students can be given exclusive responsibility for one or some categories. The students' different responsibilities force at least a certain level of participation from all students. This situation changes the game's focus more toward collaboration and dispute resolution.

Table 13.1: Potential research topics relevant to Category Schooling.

RP1	**Time pressure**
The game duration can be adjusted to many different orders of magnitude, which is a way to adjust time pressure while keeping many other variables the same. The game's mechanisms can also be changed to focus more on the time limit, for example, through the conveyor belt variation.	
RP2	**Differing student roles and role distribution**
With the saboteur role, the game has different roles with fundamentally different behavior. The saboteur tries to get in the way of the classifying group or score points at the group's expense. The group gameplay focuses on cooperation.	
RP3	**Individualized reward mechanisms**
With the saboteur role, the game has asymmetric gameplay; there is a higher-than-usual opportunity to vary reward mechanisms.	

13.2 Code World

Code World is a game where groups of students cooperate to program virtual robots to perform tasks and earn points in a virtual world. Examples of tasks include picking up and moving objects around or making it through an obstacle course. The game world is sandbox-style, with many ways of solving the same task. Group members program on the same codebase and must control the robot at quite a low level – motors and sensors.

The game should teach programming concepts such as control flow, events, variables, data structures, debugging, error detection, and fault recovery through a primary learning effect delivered through exciting levels. The game should also teach programming collaboration. Since the learning content of the game cannot be customized, it is a game concept with specific learning content.

Variations

Escape room fantasy – This game concept could use a fantasy based on the escape room trope.

Parametric design – A specific kind of shape design called *parametric design* has some philosophical and practical similarities with certain programming paradigms. In one variant of parametric design, visualized in Figure 13.1, blocks represent operations related to constructing 3D shapes, with output from one box being the input in other boxes. A graph of the boxes describes a 3D shape. In the game, this variant of parametric design can be used to make shapes that solve physics-based challenges instead, or in conjunction with, programming the robot.

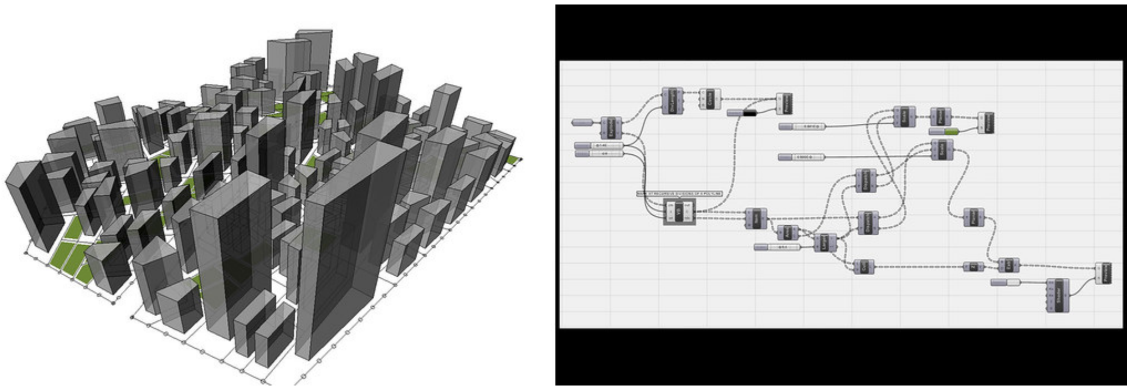

Figure 13.1: Example of block graph and resulting model in Grasshopper, an application for parametric design [65].

Research Potential

Table 13.2: Potential research topics relevant to Code World.

RP7	**Programming collaboration**
The learning content of the game is programming, and it features cooperation.	
RP8	**The escape room trope**
The escape room trope can be used in this game.	

13.3 Collective Reasoning

Collective Reasoning is a game concept where players collaborate to construct an *argument graph* [51]. The game concept facilitates collaborative reasoning exercises, and the idea is inspired by deep processing. The goal of the game is for a class or group to collaboratively construct an argument graph around a topic and construct one or more arguments as answers to a question created by the teacher within this topic. The game has flexible learning content since the teacher can formulate a question within any topic. Such a question could be "Why was it mostly European empires that engaged in large-scale colonization during and after the 15th century?" within the subject of history or "Why is Bokmål the most used written Norwegian language today?" within the Norwegian language study. The game would support interactions so the students can democratically develop the argument graph through additions, modifications, and deletions. The game would also support the construction of arguments from the elements in the argument graph in a similar manner.

Students are exposed to the knowledge and ideas of the collective. Through participation in the expansion of the argument graph, a student is faced with many terms and ideas relating to the concept at hand, as well as the numerous connections between them. The information at hand must be understood beyond pure memorization to be able to participate in the construction of arguments. Hopefully, all or most students will get a taste of the process of reasoning around arguments. This will hopefully cause the students to utilize a deep approach to learning.

Variations

Hints – The argument graph constructed by the students does not necessarily need to be constructed from scratch or without help. The teacher can provide a selection of terms already determined to be relevant for constructing an argument for the selected questions. These terms might all be present at the start of the exercise in a cluster that should be connected to the argument graph, or they can be introduced over time. Terms the teacher does not think are relevant can also be added, so the class is faced with the challenge of figuring out which words are related or not. These terms would serve as an inspiration and to get the game flowing, and not to serve as some kind of correct answer.

Roles – The game naturally has many different activities needed to complete the goal. An artificial separation of responsibilities can be created where students can only perform a couple of different tasks each. The roles can be randomly distributed or selected.

Table 13.3: Potential research topics relevant to Collective Reasoning.

RP2	**Differing student roles and role distribution**
The game can be designed to have different roles with fundamentally different responsibilities.	
RP5	**Distributed evaluation processes**
The incremental additions to the argument graph need to be evaluated somehow. The teacher could do this, but a democratic process, where students are exposed to other students' ideas, is also interesting to explore. A distributed peer-review evaluation process of contributions to the argument graph is a good solution for the game concept and makes researching distributed evaluation processes possible.	
RP6	**Deep processing**
The game concept is centered around deep processing. It can be used to test the effectiveness of game reward systems to motivate deep processing of learning content for students.	
RP9	**Acceptance of group-wide answer**
The concept of a group-wide answer is present in this game concept, but not many rewards are inherently associated with it.	

13.4 Order!

Order! is a collaborative sorting game where the goal is to sort concepts based on a given parameter. In each round, team members' phones display a visual representation of a concept, and the concepts are to be sorted by some aspect. Historical events represented by pictures can be sorted by date. Cities represented by name can be sorted by population. Mathematical expressions can be sorted by increasing value. Since the concepts to be sorted and the aspect to sort can be changed, the game has flexible learning content. The players sort the concepts by moving the phones depicting the concepts into a physical line, edge to edge. When the team is ready to test a particular sequence of concepts, one group member makes a stroke across all phones with their finger. Based on the timing of when each phone was touched, the team's answer is calculated by the system and evaluated. If it is correct, the team proceeds to the next level. The game pits many teams against each other in competitive and fast-paced gameplay. The progress of each team is displayed on a big screen visible to all players. Knowledge about the concepts is required to perform well in the game, so the game concept exhibits a primary learning effect.

Variations

Delayed question presentation – The game does not necessarily need to present the concepts and the aspect the concepts are to be sorted by simultaneously. If the concepts are presented slightly before the aspect, the players will have to think about the concepts abstractly to try to edge out a head start before the aspect to sort by is revealed. The aspect itself does not need to be presented in one go either; a word or two can be announced before the rest.

Partial sequences – The game might not require that all concepts currently displayed are used when submitting a sequence but accept any size of the sequence. The progress made by the team from completing these smaller sequences is smaller, accordingly. The mechanism can be coupled with punishment for submitting wrong sequences.

Explanations – After the players have submitted their answer sequence, the correct order of the concepts may be revealed together with the relevant information, for example, the fractions as decimal numbers or the date of the historical event. This explanation may increase learning outcomes for all players – groups that submit correct and those that submit incorrect sequences.

Table 13.4: Potential research topics relevant to Order!.

RP4	**Gradually revealing question**
The game concept fits well with gradually revealing questions.	
RP9	**Acceptance of group-wide answer**
The fast-paced and competitive gameplay might make some students susceptible to exclusionary behavior – wanting to control the group. In the context of this game, the engagement of different students and acceptance of the group answer and the team identity can be examined.	
RP11	**Exposure to surrounding facts and details**
The game concept can be designed to reveal information beyond the correct order after sequences are submitted.	

13.5 Revelicit

Revelicit is a competitive quiz game that gradually reveals extra information about the original question, making it easier. The name comes from a combination of “reveal” and “elicit”. It is a learning game concept with flexible learning content and a primary learning effect. The players will be challenged to find answers to questions that may initially be too difficult. The students must pay attention to any manifestations of the question because the actual difficulty is unknown until the student has thought about it, which can lead to higher engagement. Challenging questions can also lead the students down many different trains of thought before possibly landing on the correct path, which might help students connect the concepts on a higher level and reflect.

To increase the initial search space even further, and as a collaborative element, the game does not use multiple choice answers but rather a text field or drawing area. The evaluation of answers, therefore, becomes much more complex. After the actual answer has been revealed to the class, the task of evaluating answers is distributed to students. If the question was "Who was the explorer who started widespread European exploration and colonization of the Americas?", the answer "Christopher Columbus" would naturally give full points. However, answers like "Christ Columbus", "Columbus from Italy", or just "Columbus" could also give full or partial points. Being able to evaluate misspellings correctly could improve accessibility. In other cases, synonyms or alternate names, like "Twin Towers" or "World Trade Center", can be caught and correctly evaluated if students participate in the evaluation.

Table 13.5: Potential research topics relevant to Revelicit.

RP1	**Time pressure**
Variants of the game with and without time pressure can easily be created and tested.	

Continued on next page

Table 13.5: Potential research topics relevant to Revelicit. (Continued)

RP3	**Individualized reward mechanisms**
The game requires that each player has their own interface, meaning that individual rewards can be employed.	
RP4	**Gradually revealing question**
Gradually revealing information is present in the game.	
RP5	**Distributed evaluation processes**
The mechanism, or system, fits with the game concept. The game concept can explore how the culture or conventions for recognizing different partial scores develops and how it affects the players. One class may deduct a considerable amount of points for spelling mistakes, making the players spend more time on spell checking, while another class may be more lenient, making the players less focused on this.	

13.6 Society

Society is a historical game where each individual plays different entities, king, lord, peasant, in a society from the middle ages. The game has a secondary learning effect, as the individual goal for each player is to survive in the game and have fun. Learning history is not necessary to perform well in the game but rather a potential side effect of playing. The game will attempt to teach and illuminate contemporary humans' decision-making by presenting the era's institutions and circumstances as game mechanics.

The game concept has a specific learning content, which is the intuition of the macro-societal behavior of the military nobility, the clergy, the peasantry, nomadic pillagers, etc., during the middle ages, as well as the more specific techniques and concepts related to their everyday activities.

Table 13.6: Potential research topics relevant for Society.

RP2	**Differing student roles and role distribution**
The game concept features multiple roles with wildly different goals and play styles.	
RP3	**Individualized reward mechanisms**
The game requires that each player has their own interface, so individual rewards can be employed.	
RP12	**GameFlow in groups with asymmetric gameplay**
The interactions between players in the game are to conform to the fantasy and be relevant to the goals of the fantasy; interaction should only happen through game mechanics. These features may make it easier to achieve GameFlow, as the players do not leave the fantasy to communicate.	
RP13	**Secondary learning effect of abstract concepts**
The game concept aims to teach through secondary learning. The main goal of each individual is not strongly tied to the learning outcome of that person; in other words, being good at the game is not the same as absorbing the intended learning content. The game is set in a historical setting, with some historical concepts that are quite concrete, like what tools and techniques were available at the time, but also abstract concepts, like the reasons the peasantry would be willing to be subjects of the local duke or monarch.	

13.7 The Opinion (Norwegian: Opinionen)

The name in Norwegian comes from the Norwegian word without a literal translation – the opinion of a population. The English name is an inaccurate translation.

The Opinion is s cooperative quiz game with options for answers and where the answers of individuals in the group are aggregated into a group-wide answer. The game has flexible learning content and a primary learning effect. The group-wide answer is the answer that is ultimately evaluated and influences the group's score.

The group-wide answer is meant to represent the group's opinion and is aggregated using a voting mechanism that favors historically underrepresented voters. In the voting rounds, each player votes for one of the available options, and these individual answers are used to find the group-wide answer. It can happen that specific voters coincidentally mostly vote against what ends up being the group-wide answer, irrespective of if the group-wide answer is correct or not. Having a low representation in the answers that are being submitted might cause lower engagement and decreased learning outcomes. Increasing the voting power of historically underrepresented voters can help mitigate this problem. The voting power of historically underrepresented voters is increased by a small amount, but not so much that it is favorable to save up voting power.

Several different fantasies can be added to this concept, most of them extrinsic. For example, the class can be represented as tiny warriors that hack away at a monster when the individual correctly contributes to the class selection of the correct class-wide answer. The fantasy can also display the increased voting power of historically underrepresented voters, for example, by showing them holding a bigger weapon.

Variations

Voting system – Aggregating individuals' answers into the group-wide answer can happen in different ways. The aggregation method favoring historically underrepresented voters must be applied through a voting system. The most obvious choices are plurality voting or majority voting. A majority voting system may be applied together with a two-round system to ensure that a group-wide answer is found.

Speeches – A discussion phase can be held before answer voting, where random class members are selected to try to convince the class or at least explain the reasons for selecting a specific answer. The rounds incorporating speeches can be random, not random but hidden from participants, transparently predetermined, or every round.

Table 13.7: Potential research topics relevant to The Opinion.

RP3	**Individualized reward mechanisms**
The game concept can be designed to include many levels of goals, which all make sense to pursue at different points in gameplay based on the actions of the individual in the last couple of rounds; this allows testing out different rewards used for the different levels of goals, and how players react to these.	
RP9	**Acceptance of group-wide answer**
The concept of the group-wide answer is present in the game.	
RP10	**Engagement of misrepresented voters**
Mechanisms that affect historically misrepresented voters can be implemented in this game.	

14 Selection Process

In the specialization project [2], the game concepts were evaluated in three areas: (1) practical feasibility, (2) motivation of authors, and (3) research potential. This chapter will present the three areas and a summarized version of the results of this evaluation, including the selection of the game concept that has been developed in this project. The complete assessment can be found in the specialization project [2].

14.1 Practical Feasibility

Practical feasibility is a measure of how easy it is to develop and deploy the game concept. When it comes to the **development** of a game concept, it is crucial that the game concept is not too complex to develop within the time frame of a master thesis, as the research project will fail if the development of the game concept the project relies on fails. Therefore, the feasibility of the development endeavor is a crucial aspect of the fitness of game concepts for use in research. A prototype of the selected game concept is going to be **deployed** in educational institutions in Norway for teaching and experimentation purposes, which means that teachers must be willing to test the prototype in their classrooms, the prototype must be feasible to deploy on the devices available in schools, and the prototype must be possible to use in the classroom. More flexibility in learning content and device types will increase the practical feasibility of the game concept, as more classes are eligible to use the game concept. Table 14.1 presents the characteristics related to the practical feasibility of the game concepts.

Table 14.1: Characteristics related to the practical feasibility of the game concepts.

Aspect		Category Schooling	Code World	Collective Reasoning	Order!	Revelicit	Society	The Opinion
Learning content		Flexible	Specific	Flexible	Flexible	Flexible	Specific	Flexible
Input	Pointing[1]	Required	Required	Required	Required		Required	Required
	Text	Required	Required	Required		Required		
Output	Group[2]	Optional	Optional	Optional	Required	Required	Optional	Required
	Player[3]	Required						
Technology	Device type	Flexible	PC	PC	Mobile	Flexible	PC	Flexible
Development resources	Visual art	Low	Medium	Low	Low	Low	High	Medium
	Design	Low	High	Medium	Low	Low	High	Medium
	Coding	Medium	High	High	Medium	Medium	High	Medium

1 *Pointing input* refers to mouse and touch input capabilities.
2 *Group output* refers to group-facing output, like image projectors or smart boards.
3 *Player output* refers to player-facing output, like individual electronic devices.

14.2 Motivation

The authors' motivation for the development and the research topic is a big part of the feasibility of the potential research project. In this analysis, the focus lies on two mechanisms of motivation: (1) the motivation arising from the predicted enjoyment of the development work itself and (2) the motivation arising from the potential contributions to the field of research. Although not exhaustive, these are the most important avenues.

Table 14.2: The motivation of developers for developing the game concepts.

Developers		**J. Leithe**	**L. N. Schøyen.**
Category Schooling	Development	Medium	Low
	Research	Medium	Medium
Code World	Development	Medium	High
	Research	Low	Low
Collective Reasoning	Development	High	Medium
	Research	High	High
Order!	Development	Medium	Low
	Research	Low	Medium
Revelicit	Development	Medium	Medium
	Research	High	Medium
Society	Development	Medium	High
	Research	Medium	Medium
The Opinion	Development	Medium	Medium
	Research	High	Medium

14.3 Research Potential

All the potential research topics identified in the game concepts presented in Section 12.1 can be said to be connected to game-based learning in some way, but not all are connected to the field of the research project – applied game technology. The areas of research that each potential research topic primarily contributes to are listed in Table 12.2. The game concept selected must have substantial research potential in the field of applied game technology. Only one or a few potential research topics for a game concept would be pursued at a time, so having a lot of potential topics is not much better than having a couple. On the other hand, having no relevant potential research topics immediately disqualifies a game concept, and having only one such topic reduces the flexibility of and increases the risk associated with creating a research project around the game concept. The game concepts have therefore been categorized by the number of potential research topics contributing to the field of applied game technology – Table 14.3.

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Table 14.3: Number of potential research topics within game technology for game concepts.

Game concept	Category Schooling	Code World	Collective Reasoning	Order!	Revelicit	Society	The Opinion
Number of topics	2+	1	2+	1	2+	2+	2+

14.4 Comparison and Selection

To compare the game concepts, they must be evaluated along the dimensions discussed in this chapter. Numerical ratings were given to the game concepts along these dimensions as part of the specialization project [2], and the aggregated performance of the game concepts is presented in this section.

Comparison

The overall assessment of the game concepts is based on the values calculated for the three aspects, practical feasibility, motivation, and research potential. The specialization project [2] presents how the values were determined. The assessment is presented in Figure 14.1, where each game concept is represented as a dot in a scatter plot. The x-axis represents the motivation, the y-axis represents the practical feasibility, and the dot's color represents the research potential. A dot is colored green if the game concept has at least two possible research topics, while a dot is colored yellow if the game concept has precisely one possible research topic.

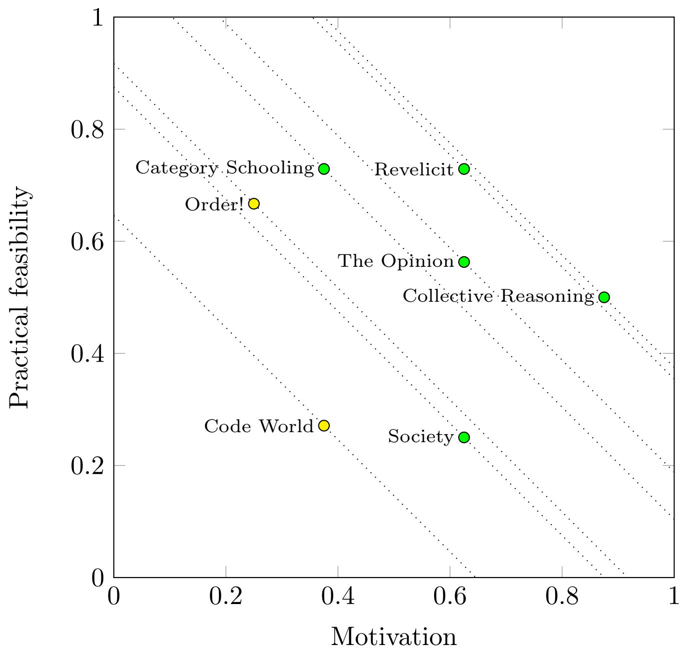


Figure 14.1: Game concepts by practical feasibility, motivation, and research potential. Higher is better along both axes.

Selection

Figure 14.1 shows that Collective Reasoning is narrowly higher rated than Revelicit and takes the top spot. Practical feasibility and motivation are valued equally. The analysis concludes with Collective Reasoning being deemed a fitting game concept for experimentation and research within the field of applied game technology. This choice does not mean it is necessarily the most fun game concept or the one with the best learning outcome, but it is promising for research.

14.5 Summary

The concepts have been analyzed and compared in regards to three areas – (1) practical feasibility, (2) motivation of authors, and (3) research potential – and the game concept *Collective Reasoning* was selected as the most fitting for future research and experimentation. *Collective Reasoning* was therefore chosen as the game concept to pursue in this thesis.

Part IV

Game Concept Description

The goal of this part is to describe *Collective Reasoning* and the reasoning behind its design. This part starts with a description of the game from a general perspective, first describing the argument graph that the players will create in the game, then describing all the elements of the game. After that, the part describes the game from the perspectives of enjoyment and learning, using the theories presented in Chapter 8 and Chapter 9. The chapters in this part are based on chapters from the specialization project [2], but all have been changed considerably.

15 | Argument Graph in Collective Reasoning

Collective Reasoning is designed to facilitate a reasoning exercise where students work together to construct arguments in the form of a specific type of *argument graph*. This chapter describes the reasoning exercise and the argument graph in detail. The following chapters describe *Collective Reasoning* in detail and clarify how *Collective Reasoning* is designed to facilitate and motivate a reasoning activity.

In *Collective Reasoning*, students play in groups and build an argument graph together to answer an open-ended session question from the teacher. Similar to the research study by *Kiili* [51], the exercise was envisioned with upper secondary students in mind, ages 16 to 19. Since it is a lecture game, each session is designed to fit within a single lecture, meaning it should last about an hour. The goal of the exercise is to cooperate to construct arguments, i.e., trains of thought, that attempt to answer a predetermined open-ended session question. The arguments will take the shape of a directed acyclic graph – the argument graph [51, 52]. A class is split into groups of around 4 to 6 students. Each group works together to create nodes of the argument graph, thereby constructing a complete argument. Each group constructs arguments independently from the other groups.

15.1 Nodes and Edges in the Argument Graph

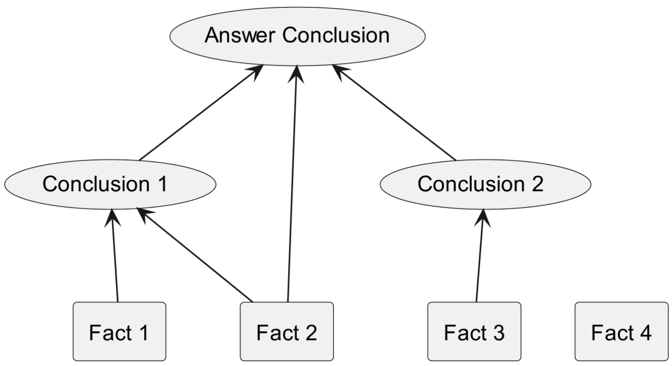


Figure 15.1: Simple illustration of the structure and elements of an argument graph created using *Collective Reasoning*.

The game's specific type of argument graph allows the players to create two types of nodes and one type of relations. The possible nodes are *facts* and *conclusions*, and the activities of the students can therefore be divided into *information-gathering* and *inference*. The only type of relation between nodes is *support*, which is a directed relation from one node to another. The *support* relation indicates that the node at the tail of the relation supports the node at the head of the relation. Figure 15.1 shows a simplified illustration of an argument graph that can be created in the game, where some facts and conclusions are connected to form a directed acyclic graph.

In the *information-gathering* part of the exercise, the students try to gather objective *facts* relevant to answering the session question. A *fact* is something that is known or proven to be true and has a source to validate it. The stock of information needs to be gathered and maintained by the students throughout the process of building the graph. It is up to the students to find sources for the *facts* and to evaluate the quality and relevance of the *facts* they find. Expanding the stock of information and writing precise descriptions of *facts* are among the activities related to *information-gathering.* A *fact* can be valid without being at the head of any support relations, as they have a source that validates them. *Facts* are meant to support other nodes.

The other part of the activity of students, *interference*, is about finding *conclusions* as logical consequences of known facts or circumstances. A *conclusion* is a judgment or decision reached by reasoning. The *conclusions* get more and more advanced as they build on each other, and the exercise is completed when an *answer conclusion* has been written and supported. The *answer conclusion* should then constitute an answer to the open-ended session question. Deduction and soundness, which require *conclusions* to follow from premises irrefutably, are impossible in some fields, e.g., history. In these cases, induction is used instead, meaning the truth only follows from premises with some probability. The quality of *conclusions* can be evaluated purely based on the premises and the internal logic, so citations and traceability are not required; in fact, the players are supposed to mostly conceive these *conclusions* themselves. **Plausibility** is an aspect that should be optimized for in *conclusions*, as it is a measure of how believable the *conclusion* is. *Conclusions* have to be supported by other nodes, as they have no outside source to support them. *Conclusions* can, however, initially be created without being supported by existing *facts* and *conclusions*; this would then not yet represent a complete and supported inference but rather a call to action on a potentially promising line of reasoning. If pursued, the *facts* and *conclusions* to support the hanging *conclusion* would then have to be constructed.

The students, in the end, use the stock of information and the *conclusions* from inference to achieve the bigger task of answering the question. It is, therefore, not a goal to have many *facts* or *conclusions* – the nodes of the argument graph – surrounding a topic if these can not be used to answer the session question. Originality and **novelty** when it comes to nodes in the graph are good qualities to a certain extent to be able to create new and interesting arguments. However, cluttering the argument graph with useless objects is bad. The students will therefore have to predict **relevance** as they filter out what *facts* and *conclusions* are worth adding or not. Another way the problem of too many *facts* and *conclusions* can manifest itself is by using many small steps to argue for something that could have been justified with fewer steps. The students should aim for **parsimony** with respect to space in this aspect, meaning to be unwilling to spend more than necessary and find efficient arguments.

The game's specific type of argument graph was created to facilitate a general reasoning exercise beyond arguing for or against a specific proposition within a topic. The argument graph created in the game is not designed to be used for debating but rather for reasoning in general. This general approach means that the game can be used to teach students how to reason in a specific subject, e.g., in history, and explore a topic to find answers to open-ended questions without having to argue for or against a specific predetermined proposition. It is a still form of argument graph, as the students argue for the answer conclusion they have formed, and they create a directed acyclic graph that supports the *answer conclusion.*

15.2 Evaluation

Teachers have a role in the exercise as evaluators. The teacher is responsible for formulating the session question and is also the one who guides the students by providing feedback on the state of their argument graph. The research by *Kiili* found that with argument graphs, teachers can better support students' post-reading activities, such as source-based argumentative writing [51]. The students are tasked with creating a source-based argument graph in *Collective Reasoning*, so as part of the game, the teachers will support the students by providing feedback.

The feedback should be specific and be given in a timely manner to ensure that the feedback given is helpful for the student. Quick feedback permits the students to act on it while the subject of the feedback is still fresh in their memory. It is not the teacher's job to provide the students with *facts* and *conclusions*, so the teacher should not be directly involved in the *information gathering* and *inference* parts of the exercise. Since the question is open-ended, the teacher should also be careful not to guide the students toward a specific answer but rather let them explore the topic independently. A way to make this possible for the teacher is to define a list of quality criteria for the nodes in the argument graph that the teacher can use to evaluate the students' work. The teacher can then use the quality criteria to give feedback to the students on the state of their argument graph.

Quality criteria for the nodes in the argument graph were designed specifically for *Collective Reasoning* and are based on the nature of the argument graph and general citation and language skills taught in school. Correct citing and precise language use are central to many subjects, as they are the building blocks of attaining and conveying knowledge. In the Norwegian curriculum for upper secondary school, they are included in the Norwegian subject in the following competence aim: "Master language morphology rules in the written first-choice and second-choice languages and write texts with verifiable use of sources and precise and nuanced language" [66]. Therefore, **clarity of presentation** is a criterion for all nodes in the graph, and **trustworthiness of source** and *traceability* are criteria for *facts*. Since the students are meant to answer a specific question in the session, the **relevance** of all nodes for this goal should also be evaluated. Due to the nature of the argument graph, the *conclusions* should be evaluated for **plausibility** and **support** since, without these two qualities, *conclusions* can not contribute to answering the question in a meaningful way. All quality criteria are *inherent*, i.e., determined from the element alone, except support, which concerns the relationships between a *conclusion* and the *facts* and *conclusions* that support it.

15.3 Summary

This chapter presented the reasoning exercise in *Collective Reasoning*. The exercise is based on the idea of forming an argument graph to answer a session question formulated by the teacher. The students are expected to work together to gather information and form inferences to answer the question. The argument graph is a directed acyclic graph, where the nodes are either *facts* or *conclusions*, and the edges are *support* relations. The teacher evaluates the nodes in the argument graph based on quality criteria defined for the exercise, listed below.

Quality Criteria for *Facts*:

- Clarity of presentation
- Relevance
- Trustworthiness of source
- Traceability

Quality Criteria for *Conclusions*:

- Clarity of presentation
- Relevance
- Plausibility
- Support

16 Description of Collective Reasoning

This chapter thoroughly describes the developed game prototype *Collective Reasoning*. As part of the description of the game, screenshots of the game are included to illustrate the game's appearance. Design decisions resulting from applying theories of enjoyment and learning in games to the game concept are sometimes included, even though the argumentation for these is presented later, in Chapter 17 and Chapter 18.

Collective Reasoning aims to facilitate the play exercise outlined in Chapter 15 in an engaging and fun way for the students. Creating argument graphs can be challenging for upper secondary students, as there are many aspects to consider when constructing arguments, and the students will likely be unfamiliar with the exercise. The game is therefore designed to have few and understandable possible actions to perform at each time and to provide a clear overview of the state of the argument. The game is also designed to appeal visually and audibly to the students to a certain degree, as the game is intended to be the center of attention for the students during the exercise. From now on, the students are the players of the game, and the teacher is the evaluator in the game.

Competitive and *cooperative* elements are central to the gameplay. The players in each group cooperate to construct an argument graph, and the group competes against the other groups to get the best score. The score is based on the quality of the argument graph and is calculated based on the quality of the *facts* and *conclusions* in the graph, as reviewed by the evaluators. The game is played on individual computers, where all players in the same group can see the same argument graph, and they all have the same available actions. Figure 16.1 depicts the relationships and interactions between different players and between players and evaluators.

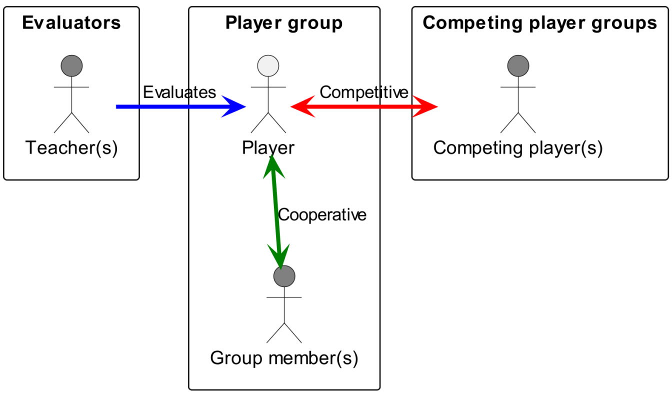


Figure 16.1: Overview of the nature of interactions between roles. The roles are represented from the perspective of the player with the white head.

Competition and *cooperation* are made possible by the players sitting together in groups in a classroom. The members of each group are co-located to allow for cooperative verbal communication. The students in a group can discuss what actions to take and how to construct the argument graph. The scores of all groups are visible on a leaderboard on the big screen in the classroom, and the scores are updated in real-time, allowing the players to see how they are doing compared to the other groups.

16.1 Game-Based Learning

To achieve research in the field of game-based learning, it is important to establish that the game idea and prototype developed are indeed that of a game and that it entails gameplay. In addition to being play, defined as "an activity engaged in for entertainment" in Chapter 6, five recurring characteristics were found to be necessary to categorize play as gameplay. The *competition* as a group working together against other groups constitutes the **agonistic dimension**. A tense situation where two or more teams are neck in neck until the last moment, an underdog story, or a comeback story can happen in the game, making up developing narratives and drama during gameplay. Since the performance, knowledge, and ideas of other students – team members and opponents alike – are unknown but have drastic consequences for the final ranking, the game can be said to have an **uncertain outcome**. The results of the activity, e.g., evaluation and argument graphs, are not to be used by the teacher or students for anything else afterward, making the activity **non-productive**. In addition, the activity has a definite start and end time and a physical location, meaning the gameplay is **separated from the real world**. **game rules** determine what the players can and cannot do, including when they can create, modify, and submit nodes of the argument graph and when they can use abilities. A more detailed analysis of how different game elements contributes to gameplay is found in Chapter 17.

16.2 Score

Three mechanisms affect the score of a group. (1) *facts* and *conclusions* are rated based on *inherent qualities* and get a score number, (2) certain actions *cost* points to perform, and (3) the *support* relations mechanism gives points based on how well-supported the *answer conclusion* is. Contributions to the score from all three mechanisms are summed to the total score number, which updates live and is visible to the player.

The ratings for **inherent qualities** of *facts* and *conclusions* usually result in a score between -150 and 350 for each node. Each quality criterion for each node is rated on a scale from 1 star to 6 stars, where 6 stars is the best possible rating. *Facts* have 4 *inherent qualities*, so they can get between 4 and 24 stars, while *conclusions* have 3, so theycan get between 3 and 18 stars. These scales are mapped linearly to the point scale from -150 to 350 points. Rated elements with a score can be seen in Figure 16.7.

The players can use **abilities** on *facts* and *conclusions* to affect the score received for a node. The **2x-ability** multiplies the score received on a node by 2. Both a positive and a negative score will be doubled by a 2x-ability, meaning its effect can be positive or negative, depending on the quality of the node. With the 2x-ability, the range of scores one node can receive is from -300 to 700 points. The **shield-ability** ensures that the node can not get a negative score. If a node receives stars that would result in a negative score, but it is shielded, they get zero points for that node instead. The abilities are used on nodes before they are submitted to review, so they can not simply be used when the score associated with a node is already known. Only one ability can be in effect on a node at a time.

The actions of deleting or starting a rework of *facts* and *conclusions* that have already been reviewed **cost 25 points** each time it is performed. It is used to discourage certain behavior. This deduction from the total score of a group is persistent. A group can perform these actions even if it would put the score below 0 points.

The **support** quality criterion is only rated at the end of the game and contributes to the score with a different mechanism than the other 5 quality criteria. It concerns the *support* relations between nodes, which can change up until the moment the game ends. Support scores are given for *conclusions* that are connected to the *answer conclusion* based on their *support* rating. The support score of the *answer conclusion* is 500 points multiplied with its *support* rating treated as a fraction, e.g., 5 stars becomes the fraction $\frac{5}{6}$. This same process is repeated for all *conclusions*, but instead of 500, the sum of support scores of *conclusions* that depend on the *conclusion* in question, divided by the number of supporting nodes each dependent *conclusion* has respectively, is used instead. If the *answer conclusion* in an argument graph is deeply supported, this mechanism can contribute about 1000 to 1500 points to the score.

16.3 The Evaluator Role

The evaluators are responsible for rating the nodes of students' the argument graphs. The evaluators should be teachers or other persons with sufficient knowledge of the subject matter to be able to evaluate the quality of the nodes in the argument graph. The evaluators should also be familiar with the evaluator interface of the game.

A thorough *evaluation guide* for how to evaluate the quality of *facts* and *conclusions* in the game was created. The guide is in Norwegian and is included in Appendix B. The purpose of the guide is to help the evaluators rate the quality of the nodes in the argument graph consistently and quickly. The guide is not intended to be used by the students but rather as a tool for the teacher. The guide specifies what should be present to receive a certain amount of stars within each quality criteria and provides examples of how many points stars results in.

Ideally, there should be at least one evaluator per two groups when playing the game. This is to ensure that the students get feedback on their argument graph as soon as possible. For this reason, the researchers will act as evaluators together with a teacher during the experiments in this thesis. Since all evaluators should use the same *evaluation guide*, having multiple evaluators should not heavily affect the consistency of the ratings. All evaluators can also rate all argument graphs and discuss their ratings with each other, which should contribute to consistency.

16.4 Player Interface

The player interface consists of three views for joining a game session and two views inside the game. Since the game is to be tested in Norwegian schools, the interface is in Norwegian. The first section describes the state flow of *facts* and *conclusions*, which will make it easier to understand the interface screenshots. The views are shown and described in the following subsections. The reasoning behind the design choices is elaborated in Chapter 17 and Chapter 18.

16.4.1 The State Flow of *Facts* and *Conclusions*

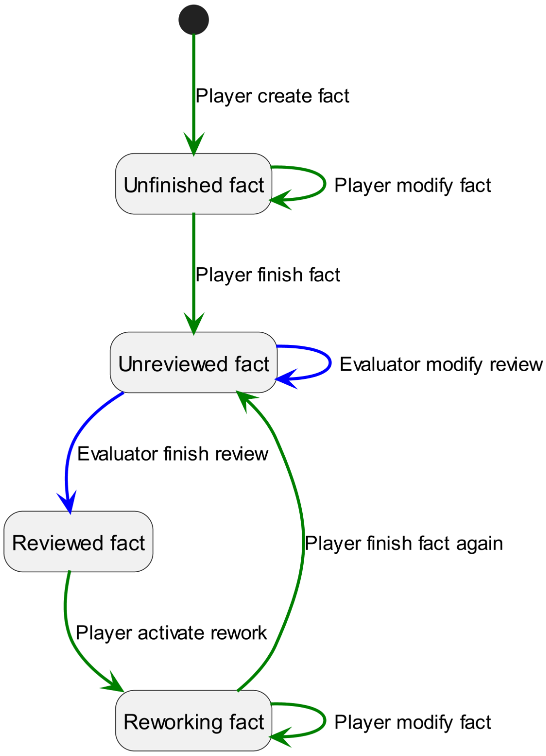
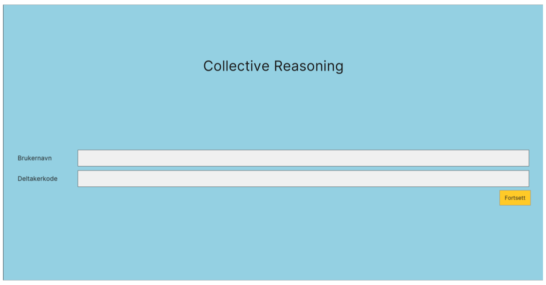


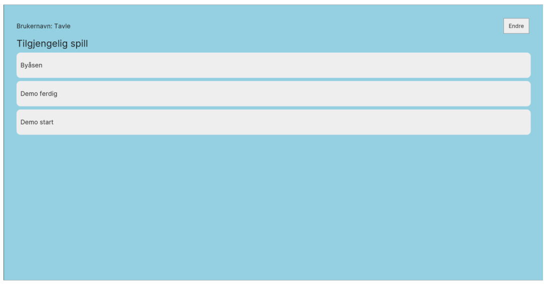
Figure 16.2: State diagram of the possible states of *facts* and select actions that are possible to perform on them in each state. States and actions for *conclusions* are identical.

Understanding the interface screenshots from the game will be easier if the reader understands the state flow of *facts* and *conclusions*. The state flow is visualized in Figure 16.2. The state flow is the same for both *facts* and *conclusions*. Figure 16.2 shows that all nodes start in an **unfinished state** where the player can modify it. When the player is done modifying the node, the player can submit it for review. The node is then in a pending **unreviewed state**, waiting for the evaluator to review it. When the evaluator finishes the review, the node is in the **reviewed state**, and the players can choose whether to rework it or leave it as it is. If they choose to rework it, the node will again be in the **reworking state**, and the player can modify it. When the player is done modifying the node, the player can submit it for review, and it is *unreviewed* and pending again. This cycle continues until the game ends, meaning the players can no longer modify the nodes in their argument graph. Any unfinished element, or ones currently being reworked, will automatically be marked finished. Afterward, the evaluators will have to finish evaluating all elements before the final scores of each group can be determined. This means that all elements will eventually end up in the *reviewed* state. During any state, the players can delete a node.

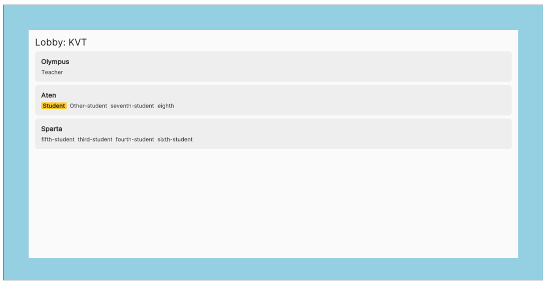
16.4.2 Join a Game Session Views



(a) Create a user view.



(b) Game list view.

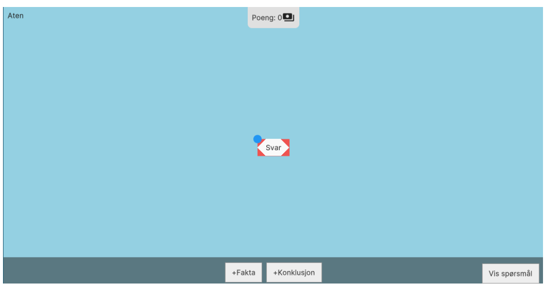


(c) Game lobby view.

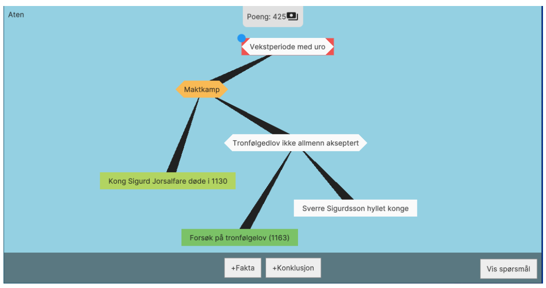
Figure 16.3: Three views to join a game session.

Figure 16.3 visualizes the three views a player must go through to join a game. The first step is to create a user by entering a username and a player code in the view, shown in Figure 16.3a. The player code is used in data analysis from the experiments to link the player to their answers to a questionnaire; it is not a part of the game. The next step is to choose a game from the list of games, shown in Figure 16.3b, which shows the game list view where there are currently three games one can join. Clicking on the game name will take the player to the game lobby view, shown in Figure 16.3c. In the lobby view, the player can see the other players in the game, and the player can see what group they are in, which will be visible once the evaluators have assigned the players to groups. In the lobby view in Figure 16.3c, there are three groups, one group of evaluators, named *Olympus*, and two groups of players, named *Aten* and *Sparta*. The player's name is marked with yellow, showing that the player who took this screenshot is in the group *Aten*.

16.4.3 Game View



(a) Game view, just started.



(b) Game view, while playing.

Figure 16.4: Two screenshots of the game view.

When the game starts, the players see the game view, where they can see the argument graph. The game view is shown in Figure 16.4 and Figure 16.5. Figure 16.4a shows the game view when the game is just started, and the argument graph consists of only one node, which is the empty *answer conclusion*. Figure 16.4b shows the game view when the players have added some nodes to the argument graph and have received some reviews from the evaluators. Figure 16.5 shows the game view when the players have added all the nodes to the argument graph and all nodes have been reviewed by the evaluators. Clicking the "Vis spørsmål"-button in the bottom right corner of the view will display the session question.

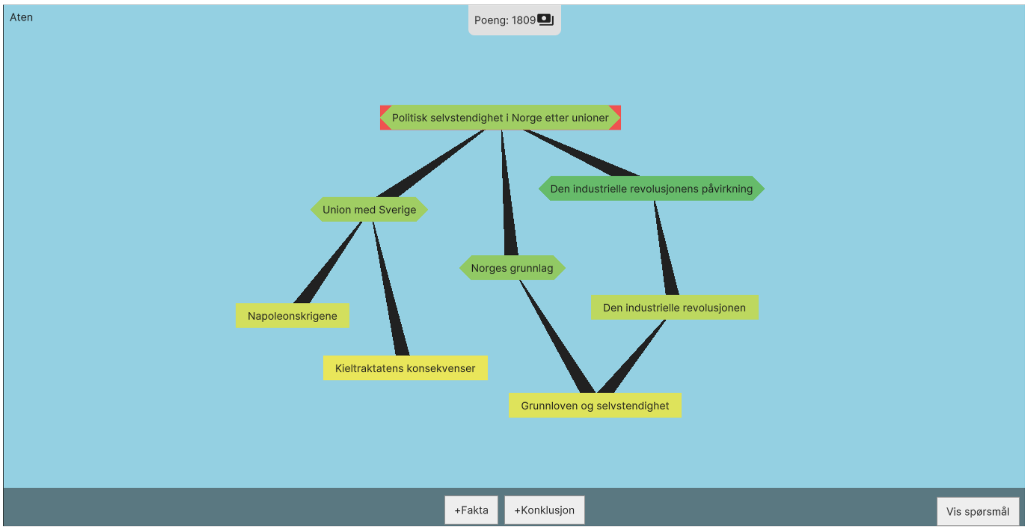


Figure 16.5: Game view, finished graph.

Adding *facts* and *conclusions* is done using buttons, and creating support relations between them is done by dragging from one node to another. The "+Fakta"-button on the bottom of the screen adds a new *fact* with the title "Ny faktaopplysning", which means "New fact". The "+Konklusjon"-button adds a new *conclusion* with the title "Ny konklusjon", which means "New conclusion". The answer conclusion is present from the start and can not be deleted, and the players can not add more than one answer conclusion. To create a support relation between two nodes, the player drags from one node to another, for example, from a *fact* to a *conclusion* or from a *conclusion* to the answer. Players may not create support relations from a *conclusion* to a *fact*, as it does not make sense to have a *fact* be based on a *conclusion*.

The shape of a node communicates the type of the node. *Facts* have rectangular shapes, as seen on the four bottom nodes in Figure 16.5. *Conclusions* have hexagonal shapes, as seen on the four nodes above the *facts* in Figure 16.5. The *answer conclusion* also has a hexagonal shape, as it is a type of *conclusion*, and it is marked with red on the sides to distinguish it from other *conclusions*, as seen on the top node in Figure 16.5.

The colors of the nodes in the argument graph indicate the state of the nodes, and a blue dot indicates that the players have work to do on a node. White nodes, which there are three of in Figure 16.4b, are nodes that have not yet received a review. If a white node has a blue dot in the top left corner, like the *answer conclusion* in Figure 16.4b, the node is not set as finished by the group; hence it is in the **unfinished state**. No blue dot on a white node means it is in the **unreviewed state**. Colored nodes have received a review, and the color reflects the score. If a colored node has no blue dot, it is in the **reviewed state**; if it has a blue dot, it is in the **reworking state**. The more green a node is, the higher score it has received. The more red a reviewed node is, the lower score it has received. For example, the dark green *fact* in Figure 16.4b has received a high positive score, the light green *fact* has a lower positive score, and the orange *conclusion* has a negative score.

There are limits to how many unfinished nodes a group can have. A group can only have two unfinished *facts* and three unfinished *conclusions* (including the answer conclusion) simultaneously. If a group tries to add more unfinished nodes, they will see a pop-up notifying them that they have reached the limit.

16.4.4 Edit Node View

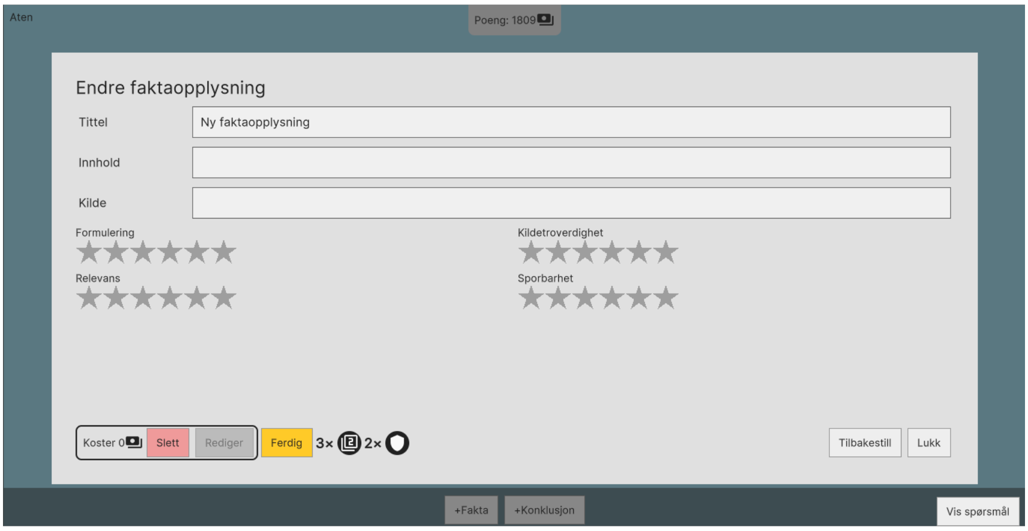


Figure 16.6: Edit fact view. Fact in the unfinished state.

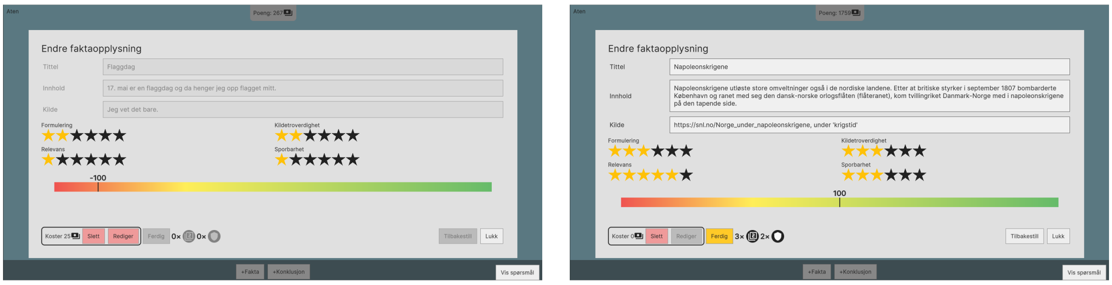
Figure 16.8 shows the view to edit a ***fact***. The view can be opened by clicking on a *fact* in the game view. The view opens on top of the game view, and the game view is blurred out in the background.

The actions the player can do in the edit view depend on the node's state. If the node is in the **unfinished state**, the players can edit the title, description, and source of the node, delete the node or set the node as finished, with or without using a *ability*. If the node is in the **unreviewed state**, the players can only delete the node. In the **reviewed state**, the players can choose to rework the node or delete it. In the **reworking state**, the players have the same actions as in the unfinished state.

Actions are done in the view using buttons and input fields. The node's title is edited in the input field titled "Tittel", which means *Title*. The description is edited in the input field titled "Innhold", which means *Contents*. The source is edited in the input field titled "Kilde", which means *Source*. The "Slett"-button means *Delete*, the "Tilbakestill"-button means *Reset*, the "Ferdig"-button means *Finish*, the "Rediger"-button means *Edit* and the "Lukk"-button means "Close". The *abilities buttons* are circular and placed on the finish button's right side. Pressing an *ability button* activates the ability, which must be done before the node is set as finished. What buttons and input fields are active depends on the node's state, and the buttons and input fields that are not relevant to the current state are grey-colored, like the "Rediger"-button in Figure 16.6.

The titles above the stars let the players see what dimensions each fact will be evaluated on. The titles of the fields are "Formulering", which means *Formulation* or *Clarity of presentation*; "Relevans", which means *Relevance*; "Kildetroverdighet", which means *Trustworthiness of source*; and "Sporbarhet", which means *Traceability*. These are the same dimensions for the quality of a *fact* as discussed in Chapter 15.

Figure 16.7 shows the view for a *fact* in the reviewed state and a *fact* in the reworking state. Both of these have yellow stars showing the review received from the evaluators. The reviewed fact in Figure 16.7a has received few stars, which resulted in a negative score, while the fact in Figure 16.7b has received enough stars to have a positive score. The score is visible as a marker on a colored gradient from red to green, indicating how good the score is compared to the maximum and minimum scores. Different buttons and fields are disabled in the two views since the *facts* are in different states.



(a) Fact in the reviewed state

(b) Fact in the reworking state

Figure 16.7: Two screenshots of the edit fact view.

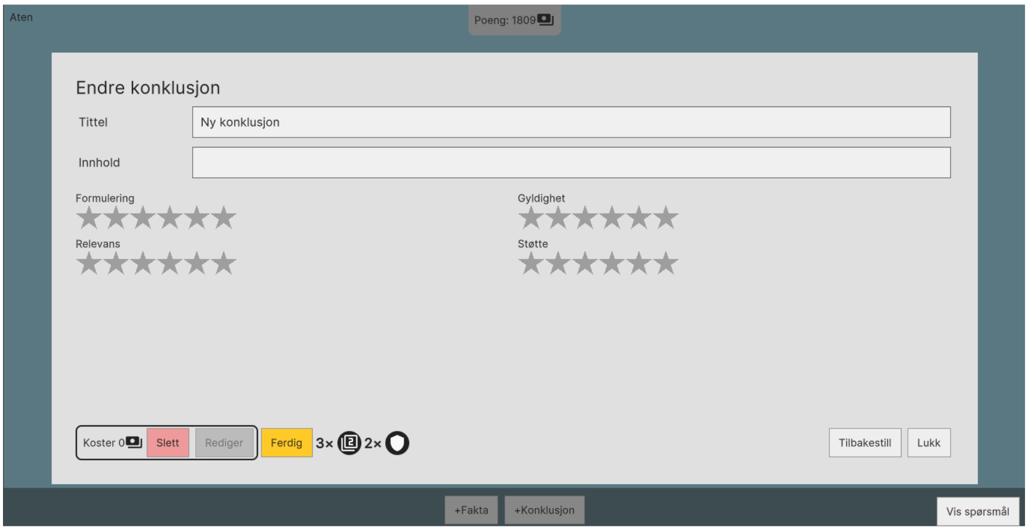
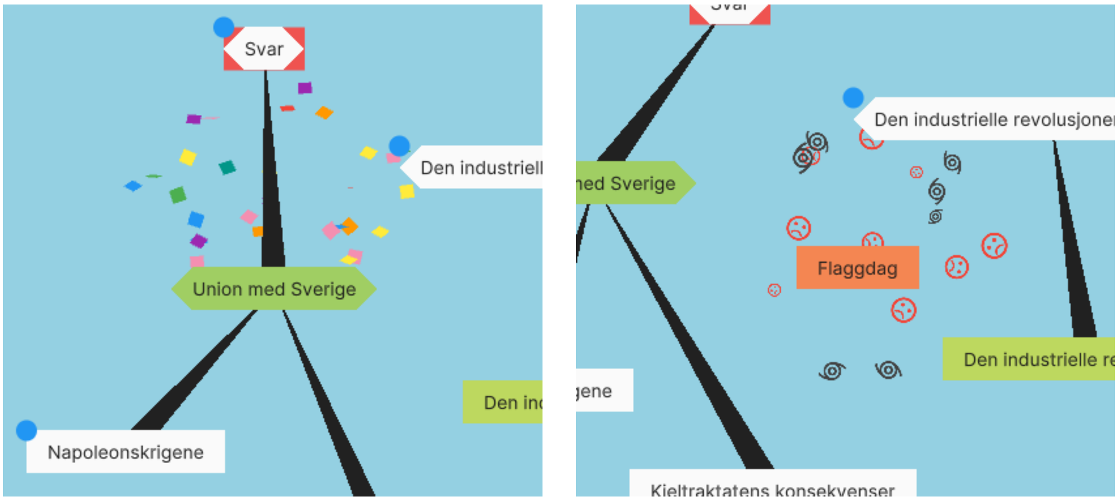


Figure 16.8: Edit conclusion view.

Figure 16.8 shows the edit ***conclusion*** view. The view functions the same way as the edit *fact* view, but the *conclusion* has no source, and the *conclusion* has other criteria to be evaluated on. The titles above the stars in the edit *conclusion* view are *Formulering*, *Relevans*, *Gyldighet*, and *Støtte*, which match the criteria for *conclusions* listed earlier.

16.4.5 Effects

When a group receives a new review on a node, they get a sound effect and visual notification. Positive scores result in a joyful sound and a positive visual effect, while negative scores result in a sad sound and a negative visual effect. The positive visual effect is a colorful confetti explosion, and the negative one is a cloud of negative symbols. The visual effect appears on the node that has received a review and is shown in Figure 16.9a and Figure 16.9b.



(a) Confetti. (b) Cloud of negative symbols.

Figure 16.9: Two screenshots of visual effects.

16.5 Evaluator Interface

The evaluator interface has views for creating a game session, dividing the players into groups and starting the game, and inside the game for reviewing the argument graphs created by the players. The interface is in Norwegian. Some of the views are shown and described in the following subsections, but since the role of the evaluator is there to facilitate the game and is not the focus of this thesis, the views are not described in detail.

16.5.1 Argument Graph View

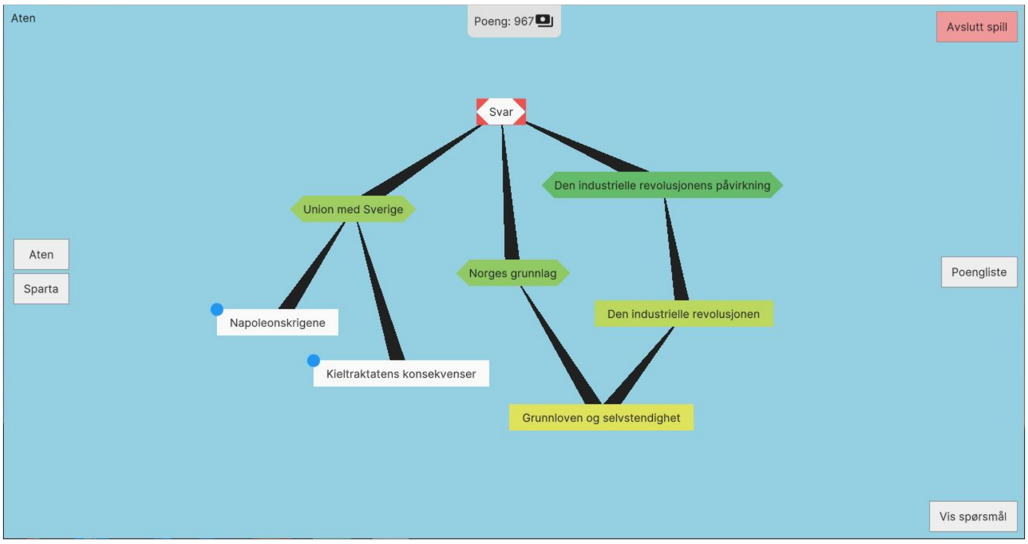


Figure 16.10: Argument graph view for evaluators.

Figure 16.10 shows the evaluators' argument graph view. The view is similar to the game view for players. However, the evaluators have a button for ending the game, a button for showing the leaderboard, buttons for choosing what groups' argument graph to look at, and no buttons for adding *facts* or *conclusions*. The red "Avslutt spill"-button ends the game, meaning the players can no longer add or edit *facts* or *conclusions*. The *Poengliste*-button opens the leaderboard. The buttons on the left let the evaluator choose which group to look at, and as seen by the name in the top left corner, the evaluator is currently looking at the Aten group. As for the players, a blue circle in the top left corner indicates that the evaluator's attention is required, which for an evaluator means it needs to be reviewed.

16.5.2 Review Node View

Figure 16.11: Give evaluation view for evaluators.

Figure 16.11 shows a screenshot of the view evaluate a *fact*, which is very similar to the view to give an evaluation to a *conclusion*. The title, content, and source of the fact are visible on the left side, and the evaluators can click on the stars on the right side to edit the review. The *fact* in the screenshot is in the *unreviewed* state, which is why they can edit the review. To finish the review, the evaluators can click the "Send"-button; this will change the state of the fact to *reviewed*. The only thing that is different when evaluating a *conclusion* is that the *conclusion* has no source, and the criteria for the *conclusion* are different.

16.6 Projector View

Figure 16.12: Leaderboard.

Figure 16.12 shows the leaderboard, which should be visible on the large screen in a classroom during gameplay. This view includes a leaderboard, which lists all the groups and their points ordered by points. This view also has a section for "Tips og Triks", meaning *Tips and Tricks*, where the player gets tips for how to play the game better. The tip currently showing means "Can you come up with an argument or reasoning you are proud of?". Other tips that can show up are related to using abilities, discussion with the group, etc. The tip shown changes every 30 seconds. The question created by the evaluator is also visible in this view at the bottom of the screen.

16.7 Summary

This chapter presented the developed game concept *Collective Reasoning*. The game is designed to engage and educate upper secondary school students through gameplay where players construct argument graphs. The gameplay involves cooperation and competition among groups, with the quality of the graphs determining their scores. The Player interface, the evaluator interface, and the projector view have been depicted and described in detail in this chapter to give the reader an understanding of the game.

17 Applying Theories of Enjoyment

This chapter describes the application of theories of enjoyment in games in Collective Reasoning. The relevant literature is presented in Chapter 8 and is made up of three articles on *Challenge, Fantasy and Curiosity* [34], *GameFlow* [35], and *Game Reward Systems* [37], by *Malone*, *Sweetser* and *Wyeth*, and *Wang* and *Sun* respectively. The theories are applied to the game to ensure that the game is enjoyable for the players. Some sections describe how the game incorporates some general aspects of enjoyment, such as *challenge* and *control*, and give theory-based arguments for why the choices made should contribute to making the game enjoyable. Other sections describe how specific game design elements, such as *feedback messages* and *accumulated feedback*, have been included for enjoyment.

Since the game is a prototype developed within a limited time frame, it is not feasible to incorporate all theories of enjoyment in a meaningful way. The emphasis has been on integrating the most pertinent and applicable ideas within the available time. As the research goal is related to the concept of *deep processing*, the focus was on creating a game that would facilitate this and incorporate enough elements of enjoyment to use the game in the research experiments. Although there were additional ideas to enhance the game's enjoyment factor, such as placing the game in a more engaging fantasy setting, time constraints prevented their implementation. These ideas are discussed further in Chapter 31, offering potential avenues for future improvements of the game concept.

17.1 Challenging the Players

The main *goal* in Collective Reasoning is to compete with the other groups in the class to receive the highest score. The challenge players will face in a game is one of the most important aspects of good game design [35] and is a repeating aspect of theories on enjoyment in games [34, 35]. The game will engage the players' self-esteem and desire to win, motivating them to play it. As mentioned by the teachers in Chapter 7, students are typically competitive and want to win, which indicates that this competition element is an effective way to motivate the students to play the game.

The game has a *score system* where all groups are ranked on a leaderboard based on their score. The leaderboard is visible to all players, updated live, and constantly reminds them of the challenge since the players can see how their score compares to the other groups. The leaderboard provides a real-time platform where the groups can measure their performance against the others, creating a sense of urgency and a drive to improve. As players strive to climb higher on the leaderboard, they are motivated to master the game's mechanics and refine their argument graph. The challenge for the group at the top of the leaderboard is to maintain their position as other groups try to surpass them. For the other groups, the leaderboard constantly reminds them of the gap between their current standing and those above, fueling their determination to surpass others and reach a higher position.

A game can challenge the player by presenting them with a goal whose accomplishment is uncertain [34]. Given that the objective is to outperform other players, the *goal* in *Collective Reasoning* undergoes dynamic changes, which contributes to an *uncertain outcome*. As the other groups change their argument graph to pursue a higher score and subsequently receive an updated score from the evaluators, the *goal* moves as the score to beat increases. Compared to a static *goal*, this dynamic *goal* can be challenging over a more extended period, as even the currently leading group knows that the other groups can surpass them unless they keep improving. With a static goal, "reaching 1000 points", for example, the same would not be true since once a group attains it, they could consider themselves accomplished and no longer driven to progress. A group does not know how many unreviewed elements the other groups have, so they do not know how many points other groups may gain within the next few seconds or minutes – *hidden information*. This uncertainty of the *goal* contributes to the challenge since the groups do not know how many points will be needed to win the game.

The first time a specific class uses the game, which will be the case for the experiments in this project, the game will be unknown to them, affecting the experience and enjoyment. The need for the players to learn the game – e.g., its rules and goal – is at its greatest. One interesting aspect of this is the meaning of the game-related concepts *fact* and *conclusion*. Another interesting aspect is the meaning of the feedback dimensions of *facts* and *conclusions* from *evaluators*. For some of these dimensions, the initial impression the players get may differ from the intended meaning, leading to groups receiving a lower score than they expected. The first time playing, a part of the challenge is to learn the game, which is a challenge that is not present to the same degree in subsequent play sessions. Since all students in a class will typically be playing the game for the first time at the same time, the stage is set for rapid class-wide improvement during the first session.

17.2 Letting the Player Feel in Control

It is important for enjoyment players to feel in control of their actions in a game [35]. In Collective Reasoning, the players choose how they build their argument graph, and they can control which *fact* or *conclusion* to work on. The players also control their strategy; they can tackle the construction of the argument graph in any order they prefer, whether top-down or bottom-up. This freedom in the game allows the players to feel ownership of the argument graph and their work.

17.3 Ensuring Opportunities for Player Skill

Gameplay should depend on a set of skills that the players can improve and master [35]; this aspect of game design is called player skill [35].

In *Collective Reasoning*, knowing when to use abilities and when to edit or delete elements is crucial for success in the game, which constitutes a dimension of skill that players need to learn. The game does not provide explicit guidance on *abilities*, requiring players to think about other game systems and determine how the *abilities* interact with them. Since players have a limited amount of ability uses, they need to use them wisely. Editing and deleting elements in the argument graph present opportunities for improvement, albeit at the cost of points. Thus, players must evaluate the situation and gauge whether the potential of gaining more points justifies the expenditure.

The concepts of *facts* and *conclusions*, as well as their quality criteria, make up another arena for players to develop their skills. By observing and interpreting the star rating feedback players get to various submissions, they can hone in on an ever more precise understanding of the meaning of the aforementioned concepts. If they understand the meaning of the concepts and are able to create *facts* and *conclusions* that answer the quality criteria well, they will get many points and stars and may feel a sense of mastery.

17.4 Social Interaction in The Game

As described in Chapter 16, social interaction in the form of cooperation and competition is present in *Collective Reasoning*. GameFlow highlights the importance of social elements in games for enjoyment and states that games should provide opportunities for social interactions [35]. The cooperation element in *Collective Reasoning* is incorporated through real-life conversation and interactions in the game, through the players working on the same argument graph. Real-life conversations as a social element are suitable for lecture games such as *Collective Reasoning* since the players are situated in the same room. The competitive element is present in the form of the groups competing against each other to receive the highest score. The competition as a group working together against other groups also constitutes the *agonistic dimension*, as described in Chapter 16.

17.5 Creating an Autotelic Experience

The game is intended to create an autotelic experience, where the students experience enjoyment from participating in the *information gathering* and *interference*, and using their knowledge to create an argument graph. A well-designed game reward system facilitates an autotelic experience, meaning the game experience is intrinsically rewarding [37]. When the player has an autotelic experience, they are motivated to play for the sake of playing, not just for the sake of the reward [37]. The multi-step process of finishing an element in the argument graph is intended to create an autotelic experience, where the players go from having an idea to a tangible result. The players will go from having an idea of what the main message of an element should be, to formulating a title and a description. After that, they will probably take a moment to evaluate their formulation, before reformulating or deciding that they are happy with the element, and setting it as finished. The creation of an argument graph that they have complete *control* over can also contribute to an autotelic experience, as the players can be motivated to create an appealing or well-constructed argument graph.

17.6 Feedback Messages

Sound effects, in combination with confetti or a negative cloud, are feedback messages to the players. A feedback message is a message that is displayed to the player when a certain action happens and is intended to give the player quick feedback on their actions [37]. The confetti and joyful sound are a form of reward, while the negative cloud and sound are a form of punishment. These feedback messages represent the feedback given on an element in the graph, but are more swift and visual than the full feedback, since players need to click on it to view the full feedback on an element. The feedback messages are intended to make the game more engaging and enjoyable for the players, since they make the game look and sound more appealing.

17.7 Accumulated Feedback

Since multiple steps exist in completing an element in the argument graph, the player accumulates feedback, which is fitting for a game played over a longer period. Accumulated Feedback means that the player accumulates feedback on their actions, instead of getting feedback instantly on each action [37]. The player receives feedback in the form of stars and a score on the *fact* or *conclusion* after they are set as finished, meaning they receive feedback on the entire element at once, not after they are finished with for example just the title or the description. Accumulated feedback is appropriate for a game played during an entire class period, since the players can get feedback regularly, and they get to choose when something is ready for feedback.

17.8 Summary

Several design decisions inspired by the theories of enjoyment in games have been implemented to enhance the players' enjoyment of the game. This chapter describes how Collective Reasoning utilizes elements from Chapter 8 to create a game that should be enjoyable for the players. Specifically, the game is designed to have a challenge, give the players a sense of control, allow them to develop their skills, and provide social interaction. The game reward system in Collective Reasoning is intended to create an autotelic experience, where the students experience enjoyment from participating in the *information gathering* and *interference*, and using their knowledge to create an argument graph. Not all of the elements presented in Chapter 8 are present in Collective Reasoning; some are not applicable to the game, while others were not implemented due to time constraints. The elements present were chosen because they were deemed to be the most important for the game.

18 | Applying Theories of Learning

Learning opportunities and characteristics within *Collective Reasoning* must be analyzed and contextualized if the later analysis is to illuminate the connection between productive learning and games. The assertion that engagement in games leads to learning is fundamental in the field of *game-based learning*, but the mechanisms and content of the game must be aligned to cause the desired learning outcome. In this chapter, the learning content will be identified and classified, and literature related to learning in games will be applied to create a theoretical backing for the learning outcome. Specifically, the utilized literature is the traditional learning theories of *behaviorism* and *social constructivism*, as well as *James P. Gee*'s techniques for learning by design in games [38].

18.1 Learning About Reasoning

The game has a significant component of *specific learning content* from the effects of reasoning on the game mechanics and an associated *primary learning effect*. These categories of classification of learning in games are described in Section 6.3. Since the gameplay, including the creation of *argument graphs* [51], is based on reasoning, persuasion, and communication, skills, goals, and methods related to these activities are engrained in the game's mechanics.

The players must learn to formulate coherent and understandable sentences and concepts to get a higher score for the *clarity of the presentation* quality criterion in the description of *facts* and *conclusions*. Unfortunately, even though written communication is a complex task, the primary way that suboptimal performance in this regard is communicated to a player is through the star rating feedback as outlined in Section 16.2. It is difficult to imagine that the player will easily understand the problem with their formulation through the star rating alone – it is essentially an integer between 1 and 6. Communication through writing is quite explicitly tied to the score, thereby the goal of the game, resulting in a *primary learning effect*. This learning effect does not change based on the configurable parts of the game – the *session question* – so it is *specific learning content*. Source citing and source criticism are two other skills that have the same relationship with the goal of the game, the same form of feedback in the game, and which, therefore, also have a *primary learning effect* and *specific learning content*.

The course of play should facilitate reasoning, but through this, tacit knowledge about reasoning is inevitably included in the game, for example, how reasoning can be performed and the goals of reasoning. It is very natural in the game to create *facts*, then *conclusions*, and then tie them together, in that order – a bottom-up approach to reasoning around the question. The delineation of reasoning into information gathering and inference, and the need for the result of reasoning to be readable and trustworthy, are other examples of implied elaboration of the concept of reasoning. These elaborations originate from the design of the learning game itself and, therefore, game designers. If players pick up on this tacit knowledge of reasoning and that understanding is useful outside of the game, this can be categorized as the *specific learning content* of the game. This knowledge, however, does not directly influence performance or progress in the game and is, therefore, a *secondary learning effect*.

18.2 Learning About the Subject

The learning game is designed so it can be used to teach a variety of different subjects and topics by utilizing different session questions. The session question should be open-ended and encourage exploration and uniqueness regarding what sections of the subject curriculum a group of players builds their argument graph from. The representation of the argument graph makes concepts and relations between them visual and graspable, as the students are able to explicate their synthesizing [51]. These concepts and relations make up the *flexible learning content* of the learning game, customized through the session question. Players are also required to process the concepts and relations between them from the target subject when developing the argument graph. This process is fundamental to their gameplay success, meaning it is a *primary learning effect*. The nature of the processing required by the players also makes it clear that the *primary learning effect* is related to deep processing.

18.3 Use of Behaviorism

The traditional learning theory of behaviorism can be used to explain why the game should result in learning outcomes. In this section, we will analyze the game's ability to teach skills in parallel, as well as the timeliness of feedback provided in the game. In behaviorism, the *input* is the circumstances that characterize a specific situation [23, 40]. When faced with a specific input, an actor will exhibit a specific response, the *output* [23]. Two fundamental hypotheses in behaviorism are that learning is achieved through encouragement and discouragement of specific responses to a specific input and that learning manifests only through changes in a learner's mapping from input to output [23]. Behaviorism disregards introspective mechanisms in a learning agent, so the responsibility falls on educators to ensure the learning process goes smoothly.

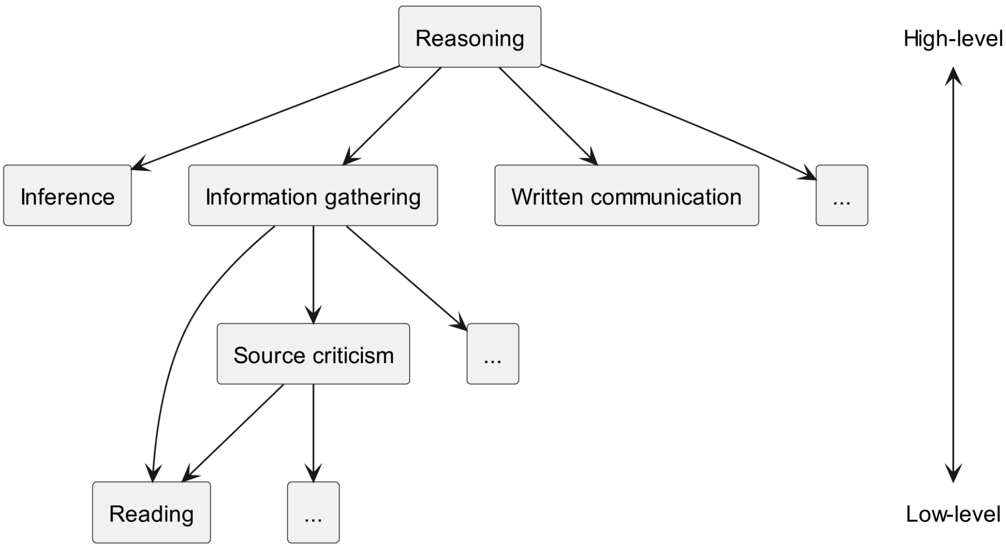


Figure 18.1: Examples of sub-skills identified as part of the reasoning skill.

The act of performing a certain skill often includes making use of other smaller skills. For example, when reasoning, one often has to gather information, infer conclusions, and communicate through writing. More examples of relevant skills and sub-skills of the reasoning exercise of creating an argument graph are visualized in Figure 18.1. Next comes two immediate consequences from the theory behind behaviorism. **(1)** Without a clear picture of the *input*, the learner cannot update their mapping from *input* to *output*, regardless of feedback on the exhibited behavior. **(2)** If multiple skills are being taught in the same situation, the feedback to each skill must be distinguishable from the feedback to other skills, or the learner will not realize which of the multiple exhibited behaviors was right or wrong. The rating given in the game when players judge the credibility of a written source is not sufficient to effectively teach the player how to read, even though the act of reading is inescapable when judging source credibility.

These consequences are being answered in *Collective Reasoning* as follows. **(1)** Tasks relating to elements are often performed in a window where other parts of the game are not shown, as seen in Figure 16.6 and Figure 16.8, establishing a context that makes the intended learning situation easy to grasp. **(2)** The application of different skills results in clearly distinguishable artifacts, such as the argument graph, *facts*, and *conclusions*, so feedback to the application of one skill can not easily be confused with feedback to another. Some examples of skills that are part of the desired learning outcome of *Collective Reasoning*, their output representations, and feedback can be seen in Figure 18.2. Note that the lowest level of skills in Figure 18.1, like *reading*, do not have feedback mechanisms, and can therefore not be said to be part of the desired learning outcome of the game.

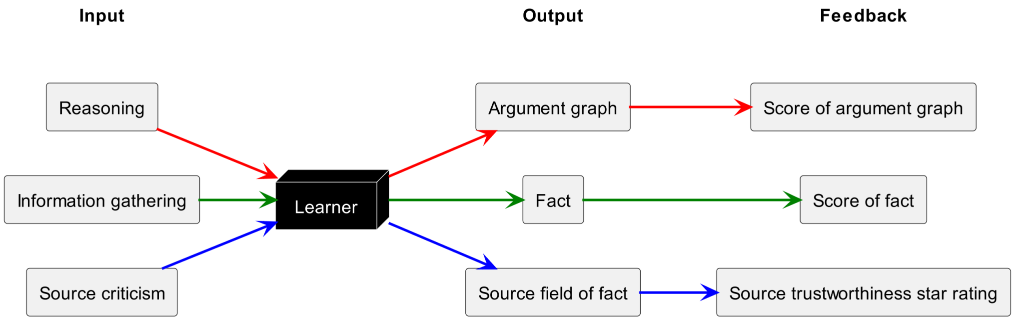


Figure 18.2: Examples of multiple skills being taught at the same time in *Collective Reasoning* and their distinct output and feedback.

Another dimension that affects how easily a learner can discern the connection between input, output, and feedback is proximity in time. Suppose the feedback is shown to the player after a considerable amount of time has passed. In that case, the learner might remember the input and their output less, or they might not even connect the feedback to the learning situation in question. The analysis of the performance of learners in *Collective Reasoning* is inherently difficult; it requires human-level intelligence and comprehension of the subject being taught, and can therefore not easily be automated. Still, the game and its deployment are designed to minimize the delay of feedback on *facts* and *conclusions*. The evaluation task is decomposed into concrete dimensions that are individually easier to evaluate. Furthermore, the evaluation guide, found in Appendix B, gives tangible recommendations for how players can achieve each star in the star rating of each quality dimension on elements, reducing the mental burden on evaluators. The game also gives visual and auditory cues whenever feedback arrives, so the players can engage with the feedback as quickly as possible. The score associated with the whole argument graph updates live whenever the scores of elements change.

Through the lens of behaviorism, the learning effect relating to reasoning is well explained. By having visually and conceptually distinct contexts of, results from, and feedback to, utilization of different skills the game should effectively teach multiple levels of skills at the same time. Although not perfect, the feedback in *Collective Reasoning* is reasonably fast, especially considering the abstract nature of the feedback.

18.4 Use of Social Constructivism

Social constructivists state that learning happens while in the *zone of proximal development* (ZPD), where learners can tackle more challenging problems than they would be alone because of their available support [41]. Books, resources on the internet, and other materials are available to the players in *Collective Reasoning*, serving as the main support for working with challenging problems within the subject, even for relatively advanced students. Through rating elements, the evaluator will also indirectly share their insight into the subject, for example, whether something is relevant to answer the question or not. As mentioned in Section 18.1, the game itself is also a source of knowledge about the reasoning process. The students support each other, both when tackling the subject and reasoning, through preexisting information and information gathered during the gameplay. Although not intended or encouraged by the game, it is possible that some players also use books and the internet to gain insight into how to reason. An overview of the support available to each learner that leads to the existence of the ZPD during gameplay can be found in Table 18.1.

Table 18.1: Support apparatus during *Collective Reasoning* gameplay, leading to a heightened ability of each learner.

Learning outcome	**Major support**	**Minor support**
Reasoning	Evaluators Group members The game	Books, internet, etc.
Subject	Books, internet, etc. Evaluators Group members	

It is not enough that people and objects are available with the knowledge required to help the learner solve difficult problems, the interactions with the support must also allow for this knowledge to become available to the learner. The communication between players should be rich and allow for the breadth of knowledge to be conveyed, which is the case since the players are co-located and can discuss freely. The players are required to write quite a lot of text while constructing their argument graph, which is also quite a rich representation of knowledge. By limiting the number of possible parallel developments on the argument graph, two new *facts* and two new *conclusions* at a time, the players are encouraged to cooperate on the same tasks, making their support available to each other. The main interaction between the players and evaluators is through star ratings of elements in the argument graph, which is quite a crude communication method. Physical distance and organization of the activity do not encourage players to rely on the evaluators, i.e., the teacher, for explanations of the subject or reasoning, but it is possible if the need arises during the gameplay session.

Social constructivism also theorizes that the meaning and understanding of concepts and phenomena are necessarily developed in groups through social processes, so the interaction should include normal socializing, which Collective Reasoning does to some degree.

18.5 Learning by Design

Among the techniques presented by James P. Gee [38] that games use to cause learning without complaint, Collective Reasoning is compatible with a number of them. The arguments that players create and the content they learn are very much affected by the character of the player, resulting in the uniqueness of the product and learning, and a feeling of ownership. Improvement on any one quality criterion of evaluation of elements results in the same increase in score, except for the support criterion, which means players are free to choose which to focus on or focus on first. These are both examples of **co-design** and motivate players to learn [38]. The session question that players attempt to answer should be crafted to allow for numerous and even unexpected approaches so that groups of players can choose an argument to pursue based on difficulty if they see multiple candidates. The evaluators that will judge the work of players possess human-level intelligence and can appreciate and reward *novelty* and *parsimony*, as well as technically good arguments, better than algorithms. This opportunity for players to choose a level of difficulty can make the gameplay **pleasantly frustrating** – not so easy that it is trivial, and not so hard that it is demotivating [38].

18.6 Summary

The learning outcome of the game has been viewed from several perspectives, namely the traditional learning theories of behaviorism and social constructivism, and James P. Gee's techniques for learning by design in games. The game and gameplay exhibit ample opportunity for learning outcomes backed by theory, both for reasoning and for the topic of sessions. An overview of significant findings can be found in Table 18.2.

Table 18.2: List of important findings regarding learning outcomes in *Collective Reasoning*.

Behaviorism	It is clear from the game context what task the player is currently doing and what skill they should be learning.
	Feedback on using different skills are distinct and given reasonably quickly.
Social constructivism	Students have textbooks, the internet, evaluators, the game itself, and each other that can support them in solving hard problems.
	Players interact with their support in ways that convey a reasonable breadth of knowledge.
Gee's techniques	If the session question is open-ended, the players can co-design their learning experience by constructing their own arguments.
	Human evaluators means that even complex and advanced characteristics, like novelty and parsimony, can be rewarded.

Part V

Game Concept Implementation

This part describes the development methodology and technology solution. Chapter 19 presents the development methodology – the strategy and process of the development phase. Chapter 20 describes some interesting aspects of the game implementation, like technologies used and influential architectural patterns applied. The information in this part can serve as an example or data point on implementing a learning game facilitating deep processing.

19 | Development Methodology

This chapter will describe the development methodology applied to create the game *Collective Reasoning*. The two researchers in this project developed the game in about three months, partially in parallel with working on other parts of the project. *GitHub* was used for hosting the codebase and for version control. This chapter includes tools and strategies used in development process.

19.1 Agile Development

An agile software development methodology was used to develop the game. Agile software development is a conceptual framework for software engineering that anticipates the need for flexibility by working in short iterations [67]. An agile methodology was chosen for this project because it is well suited for projects with changing requirements, which can be the case for research projects.

The four core values in agile software development stated in *The Agile Manifesto* [68] have been used as guidelines for the development process. *The first value* is “Individuals and interactions over processes and tools”. This value has been interpreted as the importance of communication and collaboration between the developers for this project. The developers have had meetings multiple times a week to discuss the project’s progress and update each other on the work that has been done. *The second value* is “Working software over comprehensive documentation”. For this project, the documentation was kept to a minimum level, and the purpose was to ensure that the developers were on the same page and that the game’s architecture was maintainable and scalable for the project’s scope. *The third value* is “Customer collaboration over contract negotiation”. This project has no external customers, but since the game is developed for research purposes, the developers have had to ensure that the game is suitable for the research experiments. The developers are also the researchers, so it was essential to simultaneously think about the game from both a developer’s and a researcher’s perspectives. *The fourth value* is “Responding to change over following a plan”. This value emphasizes the importance of adapting to changes in requirements and priorities. This value was especially influential for this project, as the requirements and priorities have changed throughout the development, and short iterations helped with staying flexible to changing requirements.

The game was developed in iterations. The development process consisted of one weekly iteration meeting and multiple meetings every week with discussions about the progress. The iteration meeting was used to plan the next iteration by discussing, defining, and choosing user stories that should be worked on the following week. A user story describes a software feature from the end user’s perspective (see Section 19.3). Multiple tasks were created for each user story, specifying what must be implemented in the application to complete the user story. There was no rigid structure for the meetings, but they typically started with a discussion about the progress of the project and what should be done next. User stories were also added between the iteration meetings when needed.

19.2 Kanban Board

A kanban board was used in this project to keep track of the tasks that needed to be done. A kanban board serves as an agile project management tool designed to help visualize work, limit work-in-progress, and maximize efficiency [69]. A *GitHub project board* was used as a kanban board in this project. Using a *GitHub project board* was convenient, because the codebase was hosted on *GitHub*, and the kanban board was integrated with the codebase. A screenshot of the kanban board can be seen in Figure 19.1. The kanban board contains tasks, also known as *GitHub* Issues, placed in columns based on their status. The kanban board had the columns “Todo”, “In progress”, and “Done”. In addition, the kanban board has a “Stories” column, which contains user stories. The user stories are the source of many of the tasks, as they describe the game’s functionality in a broader sense than the specific tasks.

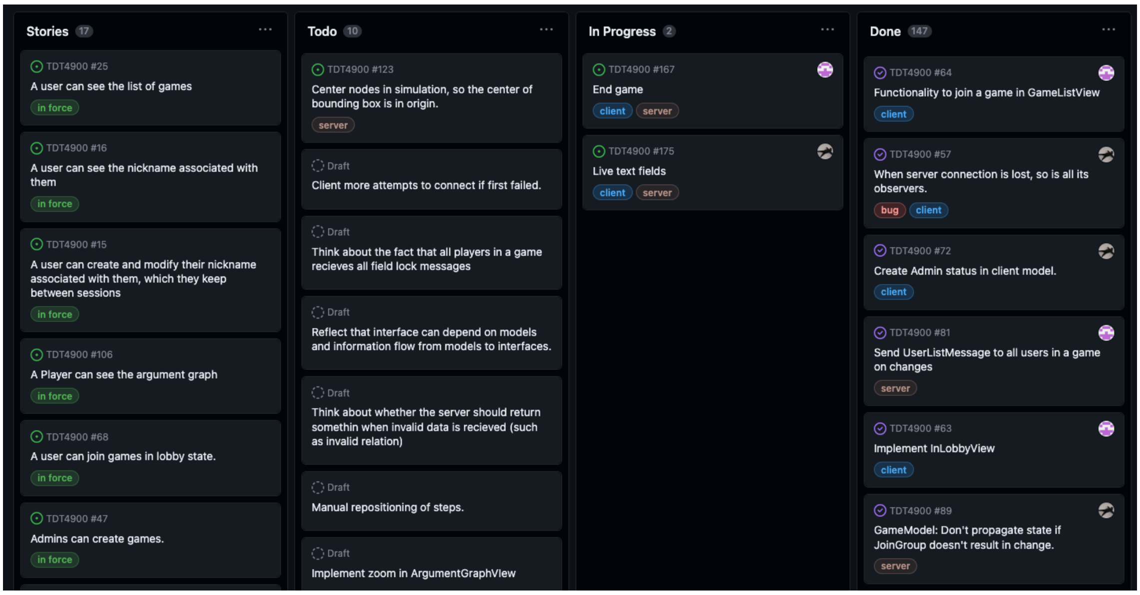


Figure 19.1: The kanban board used in the development process.

The kanban board was updated whenever a task was worked on, and new elements were regularly added to the “Stories” and “Todo” columns. New tasks and stories were typically added during iteration meetings as new tasks and stories were discovered. A task typically had labels indicating what work needed to be done, such as “client”, “server”, and “bug”. When a task was moved from the “Todo” column to the “In Progress” column, the task was assigned to the developer who was going to work on it. When a task was completed, it was moved from the “In Progress” column to the “Done” column. A task was considered completed when the code was written and manually tested. The user stories stayed in the “Stories” column, but received the label “in force” when they were completed. The kanban board was used to keep track of the tasks that needed to be done and to ensure that the tasks were completed.

19.3 User Stories

User stories were used to keep track of the requirements for the game. A user story is an informal, general description of a software feature from the perspective of the end user [70]. The user stories aimed to present how what was being worked on would bring value to the end users. User stories were also used to keep track of all functionality currently implemented in the game, as well as functionality that should be implemented in the future.

All the user stories implemented in the game are included in Table 19.1. The user stories are categorized into user types. The user types are “A User”, “A Player”, and “An Evaluator”. All users are either a player or an evaluator. In the experiments in this project, students are players, while the teachers and the researchers are evaluators. The user stories are formulated from the user's perspective, and describe something that the user type can do or observe in the game. Other ideas for user stories were also discussed, but they were not implemented in the game.

Table 19.1: User stories for the game *Collective Reasoning*.

A User can	
us1	Create and modify their nickname associated with them, which they keep between sessions
us2	See the nickname associated with them
us3	See the list of games
us4	Join a game in lobby state
us5	See all players in the game lobby they are in
A Player can	
ps1	See the argument graph
ps2	See the session question
ps3	See the name of their group
ps4	Add nodes (facts and conclusions) to the argument graph
ps5	Create and delete support relations between nodes
ps6	Open the edit view for a node
ps7	See the dimensions a node will be rated on before it has received a rating
ps8	Modify fields in a node
ps9	Save their modifications a node
ps10	Reset their modifications on a node
ps11	Delete a unreviewed node for no cost
ps12	Use a the 2x score ability on a node
ps13	Use a the shield score ability on a node
ps14	Set a node as finished
ps15	See the stars from a rating on a reviewed node
ps16	See the score from a rating on a node
ps17	See confetti or a negative cloud around a node in the graph when a rating is received
ps18	Hear a positive or negative sound effect when a rating is received
ps19	Delete or start reworking a reviewed node for the cost of 25 points
ps20	See a live updated group score
ps21	See the state of a node (unfinished, unreviewed, reviewed, reworking) in the argument graph

Continued on next page

Table 19.1: User stories for the game *Collective Reasoning*. (Continued)

An Evaluator can	
es1	Create a game with a name and a session question
es2	Take on the evaluator role in a game lobby
es3	Organize all players in a lobby into groups
es4	Start a game from the lobby
es5	Choose a group and see their argument graph
es6	Open rating view for a node
es7	Rate a node on its relevant dimensions
es8	Open a live updated leaderboard with all groups
es9	See the session question on the leaderboard
es10	See tips&tricks on the leaderboard
es11	End a game

19.4 Summary

The game *Collective Reasoning* was developed using an agile development methodology. Tasks and user stories were created when they were discovered, and their status was constantly updated in a kanban board. The kanban board was used to keep track of the progress of the development of the game. The next chapter gives more insight into the technical details of the developed game.

20 | Technology Solution

This chapter outlines some important details about the technical solution of our game, *Collective Reasoning*. This chapter presents the choice of technology platforms that the game was developed in and some reasons for choosing them. Key characteristics of the software architecture of the developed game, as well as design patterns, are discussed.

20.1 Platforms and Technologies

The game was implemented using a couple of noteworthy platforms and technologies. **WebSocket** was chosen as the communication protocol between the server and clients for its ease of use and widespread support by libraries and platforms. WebSocket is a bi-directional message exchange protocol. The **frontend** – the user-facing part of the application – was developed in **Unity**. *Unity* is a game engine that simplifies creating games by facilitating functionality especially relevant to game development. Such functionality includes customizable 2D and 3D graphics, support for many input methods, and physics simulation. The scope and needs of the game had yet to be finalized. *Unity* is feature-rich, and the platform has a big independent community extending its functionality. Therefore, *Unity* would most likely not limit our options. The **backend** – in this case, a facilitator of synchronization and logic happening behind the scenes – was developed with **.NET 7.0**. *.NET 7.0* is a general-purpose software framework for creating applications that run on Windows, macOS, and Linux. *.NET 7.0* has a template that makes it especially easy to create servers that support WebSocket connections, which is why it was chosen. The backend was deployed to a virtual machine in the *Google Cloud Platform* and accessible through *HTTPS* to make it as available as possible.

20.2 Software Architecture

This section presents an overview of the key characteristics of *Collective Reasoning's* software architecture. The software architecture aims to improve the codebase's modifiability and understandability and improve the feasibility of the development endeavor.

20.2.1 Client-Server

Between the two main architectural patterns for the responsibilities of nodes in a distributed system – *peer-to-peer* (P2P) and *client-server* – the *client-server* has been chosen for its simplicity. This means that *Collective Reasoning* as a software application has one node – the server, running the *backend* – which all other nodes – the clients, running the frontend – connect to and rely on for the application's network requirements [55]. In P2P systems, all nodes are *peers* with the same responsibilities, meaning they all must be able to contribute some resources to fulfill the responsibilities that a server would in a *client-server* system. More thorough descriptions of these architectural patterns and their advantages and disadvantages are presented in Section 11.1. The theoretical advantages of P2P, including *fault tolerance*, *scalability*, and *performance* [56], do not outweigh the disadvantages, complexity and security [56, 57] for this development endeavor.

The server's responsibility in our game is to store and maintain the application's state and perform some calculations. An example of the state the server maintains is the content and layout of the argument graphs of the groups. It also acts as the arbiter if two group members submit conflicting changes, accepting the one that arrives first. The communication between each client and the server is achieved with WebSockets.

The server calculates the positions of nodes in the argument graphs with **force-directed graph drawing** – one example of computations the server is responsible for. With this technique, desirable characteristics of the final layout are modeled as physical forces. If the distance between two nodes should be as close to a target value as possible, a force based on *Hooke's law* can be used to punish deviations from this target distance linearly. A force like this is suitable for keeping elements of argument graphs that are connected with a *support relation* the proper distance from each other. If nodes should not get too close, a force based on *Coulomb's law* can be used to punish closeness between any pair of nodes quadratically. A force like this can be used to ensure nodes in argument graphs do not render on top of each other unless necessary. Good layouts can be found for a graph by creating a physics simulation with these forces acting on bodies representing the nodes in the graph and letting it simulate for some time. The bodies will soon collapse into a layout that minimizes punishment, exhibiting the target characteristics. All layouts of argument graphs in screenshots from the game found in Chapter 16 and Chapter 25 were automatically computed by the server using this method.

20.2.2 Module-Component Mapping

In software architecture, a *component* is an *abstract unit* of the *runtime behavior* of an application with a distinct and cohesive set of functionality it is responsible for [71]. Examples of behavior that in some applications are implemented as *components* are logging of data, implemented as loggers; interfacing with external devices, implemented as drivers; and managing application state, implemented as models. *Modules* are *small concrete units* of an application's codebase with a specific computational responsibility [71]. *Modules* manifest as different artifacts for different programming languages, like files, objects, classes, packages, and assemblies. For *C#*, the programming language used in both *Unity* and *.NET 7.0*, "classes" and "assemblies" are constructs whose boundaries can be used to separate the codebase into *modules*. New runtime responsibilities that needed to be implemented in the game were carefully integrated into the partitioning of preexisting responsibilities, so that at most one component emerged from each module, and that there was high correspondence between the responsibilities of modules and components. This increases *cohesion* and reduces *coupling*, again leading to increased *modifiability* and *understandability* [71]. Some modules, however, do not result in components, such as utility files – our name for files with collections of heavily used functions that make sense to be used from anywhere and with no side effects.

20.2.3 Component Types and Model-View-Controller

Throughout the development of the game, we maintained a list of all possible component types. Each type of component maps to a type of responsibility. The final component types and their responsibilities are found in Table 20.1. The component types evolved over time but ended up coinciding with the Model-View-Controller architectural pattern [71]. Each component type is described by its main overarching responsibility and by a set of permissions that components of each type have. Components of the *Model* type are responsible for maintaining the application state in some way. Components of the *View* type are responsible for user interactions – showing the application state and presenting controls to take user input. Components of the *Controller* type listen to broadcasts about user input from *Views* and interprets them as user intent. A component cannot have any side effects other than those specified by the permissions of its type. The *ServerAPI* and *ServerConnector* components are two components whose sole responsibility is to enable *Model* components in the backend and the frontend to communicate with each other like they were not on different computers. Figure 20.1 shows what types of messages are sent between the collections of components and how they are distributed. Note that *Models* send state change messages to each other. The number of ways components interact, limited by their permissions, is kept low, improving modifiability and understandability [71].

Table 20.1: Component types, their responsibilities, and permissions.

Name	**Responsibilities**	**Permissions**
Model	Maintain state in RAM	Maintain state (at all)
		Broadcast state snapshots
		Listen to state snapshots broadcasts of Models (or the ServerConnector)
		Send state change commands to Models (or the ServerConnector)
		Send queries to the ServerConnector
View	Facilitate interaction with users	Listen to state snapshot broadcasts of Models
		Display application state to users
		Display controls to users
		Broadcast user input
Controller	Translate input to user intent	Listen to user input broadcasts of Views
		Send state change commands to Models
ServerAPI	Facilitate cross-network Model to Model communication	...[1]
ServerConnector		

[1] Presenting the permissions of the *ServerAPI* and *ServerConnector* is not that important because there is only one of each. Permissions are not needed to keep many components of the same type similar.

We illustrate this component structure with an example: storing and displaying a user's username. The *IdentityModel in the server* is responsible for storing and accepting manipulations to the identities of all users. The *IdentityModel in the client* is responsible for storing the identity of the user playing on that client; it listens to broadcasts from the *IdentityModel in the server* through the *ServerAPI* and *ServerConnector*, and updates its state if a relevant broadcast is received – one regarding its own identity. Many components listen to the *IdentityModel in the client*, but one of them, *GameListView*, listens to broadcasts about the identity changing and displays the name of the user – a part of the identity – to the user if they view the *Game List* interface, shown in Figure 16.3b.

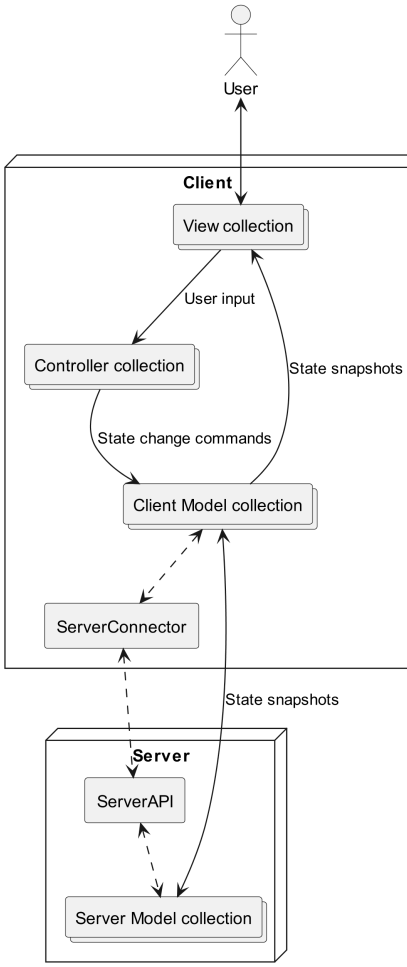


Figure 20.1: A diagram showing component types, message passing between them and nodes.

These component types and chain structures can be used to implement all functionality needed in our game *Collective Reasoning*, and for new functionality, it is easy to figure out the chain of components that must be changed or created. It is usually a chain going from user input down to the server, through a *View*, a *Controller*, some *Models* in the client, the *ServerConnector-ServerAPI*-bridge, and then up again to be displayed to the user by a *View* component. Since the number of component types is kept low and different components of the same type are very similar, the tooling around them can become sophisticated. For example, creating a *Model* includes little code. All that was necessary was to specify the data type of the state that the model should be responsible for and how the state should be changed. The tooling would automatically add broadcasting of state changes through the *Observer* pattern, subscribe all appropriate *Models* and *Views* to the broadcast runtime, ensure good concurrency behavior – e.g., no deadlocks and race conditions – and inject the component into all other components that need a reference to it. The *Dependency Injection* system will be described in more detail in Section 20.3.

20.3 Dependency Injection

Dependency injection is a design pattern used to reduce coupling. A component exhibiting behavior to fetch or create a new component is an example of coupling since it depends on the implementation of the way it is fetched or created. On the other hand, if, from the component's perspective, it simply uses the components it needs and another system finds this dependency and injects the appropriate component – dependency – at some point before it is used, the coupling is gone. This is *dependency injection* [72]. This also opens up for using polymorphism to request a specific role and getting a component injected without knowing or caring about the implementation details, for example, that the component injected might include more functionality than requested.

In our game *Collective Reasoning*, components only appear and disappear when the scene changes – e.g., going from the *Game List* interface to the *Game Lobby* interface. In these moments, the map from roles to components that can fulfill those roles is updated, and the dependencies are injected into all components based on the role that is needed. This includes both filling references or subscribing components to broadcasts or *observables*, depending on how they depend on other components. The dependency injection system uses reflection heavily, the property that code analyses other code, or itself, and changes itself, and thereby its behavior, in response.

20.4 Summary

Some characteristics of the technical solution have been highlighted. The technology *WebSocket* and the platforms of *Unity*, *.NET 7.0*, and *Google Cloud Platform* were chosen for their practicality, flexibility, synergy, and availability. The software architecture of *Collective Reasoning* follows the *client-server* architecture pattern for its simplicity, and it uses the *Model-View-Controller* architecture pattern and the *dependency injection* design pattern for reducing coupling, which again improves modifiability. The responsibilities of different aspects of the application, for example, the server and components, are presented.

Part VI

Experiment

The purpose of this part is to describe the experiment conducted as part of the research in this thesis. It is essential to describe the experiment in detail to be able to evaluate the results and conclusions drawn from them. The experiment is first described from a design perspective, then from a data generation perspective, and finally from a reliability and validity perspective.

21 | Experiment Design

This chapter will cover the design and execution of the experiment conducted in this project. The experiment is designed to give results that can contribute to answering the research questions. This chapter describes the design of the experiment, which is designed to align with guidelines presented in *Researching information systems and Computing* by *Oates* et al. [9]. Ethics and privacy concerns are also addressed.

21.1 Experimentation Population

The target audience for the game is upper secondary school students, and for the experiment in this research project, history classes with 12th-year students were chosen as the target sampling frame. *Collective Reasoning* has a significant component of flexible learning content, meaning it could be used in multiple different subjects in the upper secondary school curriculum. However, to ensure that the subject is not a variable that could cause the results to be skewed, and to reduce the number of variables that could affect the results [9], it was decided only to use one subject in all the experiments. 12th-year history classes, which have 17-18-year old students, were chosen for two main reasons. (1) The **competence aims** in history align with the specific learning content of the game. A competence aim in history is to "explore the past by asking questions and obtaining, interpreting, and using various types of historical material to find the answers" [73]. The second part of this aim aligns with the *information gathering* and *interference* aspects of the game. (2) There is **no exam** in second-year history, meaning that the students would not be preoccupied with studying for an exam, increasing the likelihood that the teachers would be willing to let their class participate in the experiment.

The experiment was conducted with three classes from upper secondary schools in Trondheim. Through contacting teachers at three different upper secondary schools, two teachers at different schools agreed to participate in the experiment. One teacher had one history class we could do the experiment with, while the other had two history classes, resulting in the experiment being conducted a total of three times, once per class. In total, 77 students participated in the experiment, which is a relatively large sample size, given the rule of thumb saying that one should have at least 30 samples for small-scale research projects [9].

Since the experiment is conducted on all students in each class, which can be viewed as a cluster, this is an example of *cluster sampling* [9]. Cluster sampling is a method where naturally occurring groups or clusters are sampled rather than individuals [9]. Cluster sampling is considered a probabilistic sampling technique, which indicates that it is likely that the sample is representative of the population being studied [9].

21.2 Experiment Description

Before conducting any experiment, a meeting with the teacher was held. The purpose of the meeting was to define a session question for the class and introduce the teacher to the game, including the evaluator interface presented in Section 16.5. The teacher being familiar with the evaluator interface before the experiment was important, as it would allow them to give faster feedback to the students in the game. The meeting was also used to introduce the teacher to the evaluator guide.

The session question for all three classes was on a topic that the students had not yet covered in class. The questions were in Norwegian in the game; English translations are provided here. Two of the classes had the question “What were the causes of Norway becoming more politically independent around the start of the eighteen hundreds?”. The third class had the question “What consequences did the meeting between Europe and America have, and what consequences can we see today?”.

Each experiment was allocated a total of 1 hour and 20 minutes with the class. A time plan was created to ensure that all experiments were conducted as similarly as possible. The time plan acts as an outline for the experiment and is shown in Table 21.1, where each step is allocated a time frame and described.

Table 21.1: Time plan for experiments.

<table>
<tr><td>15 minutes</td><td>Intro, demo, and download</td></tr>
<tr><td colspan="2">The researchers introduce themselves, the experiment, and the game. The participants are informed of their rights and provided a link to a site with the information document. The same site also has a link to the questionnaire and a link to download the game. A demonstration of the game is held. The demonstration includes showing the game interface and how it works, and presenting definitions and examples of important aspects of the game, such as fact, conclusion, and support relation. The students are told that the winning group will receive NTNU merchandise as a prize.</td></tr>
<tr><td>50 minutes</td><td>Gameplay</td></tr>
<tr><td colspan="2">The students play the game with the session question provided by the teacher. The groups are created at random, using the group creation feature in the game, and the groups sit co-located in the classroom. The teacher and the two researchers take part in the game as evaluators. The leaderboard is shown on the large screen in the classroom. The students are told how long they have left to play the game at regular intervals.</td></tr>
<tr><td>15 minutes</td><td>Questionnaire and outro</td></tr>
<tr><td colspan="2">The players fill out an online post-game questionnaire. The last minutes of the experiment are used to show the leaderboard, declare a winner group, hand out the prize, and thank the students for participating.</td></tr>
</table>

As mentioned in Table 21.1, both the teacher and the two researchers in this project will be evaluators in the game. This is to ensure that there is at least one evaluator per two groups, as discussed in Section 16.3.

21.3 Ethics and Privacy

To ensure that the rights of the participants are respected, the experiment was conducted in accordance with ethical guidelines for participants in research [9]. The five rights of participants presented by Oates et al. are: (1) The right to not participate, (2) The right to withdraw, (3) Informed consent, (4) Anonymity, and (5) Confidentiality [9]. The participants were informed of their rights before the experiment, and they were allowed to withdraw at any time. The participants were also informed that the data collected would be anonymized and that the data would be kept confidential. An information document was provided through a link, in which the participants were informed of their rights, including how to contact the researchers if they wished to withdraw their consent. The information document is included in Appendix D.

To be allowed to process personal data in a research project in Norway, it is necessary to apply for permission from a government committee or agency. Therefore, a notification form for personal data for the research in this project was sent to Sikt, which is the Norwegian Agency for Shared Services in Education and Research (formerly called NSD). The notification form received approval on 2023-01-21. The form included information on the personal data that would be collected, the test population, responsible persons, documentation, how data is processed, data security, and project duration. The form also included the information document provided to the participants. The notification form sent to Sikt is included in Appendix E.

21.4 Summary

The experiment as part of this research is conducted with three history classes from upper secondary schools in Trondheim. A detailed time plan for the experiment is presented, created to make all the experiments as similar as possible. The experiment is conducted in accordance with ethical guidelines for participants in research, and a notification form for personal data for the research in this project was approved by Sikt, which is the Norwegian Agency for Shared Services in Education and Research.

22 | Data Generation and Analysis

This section describes the four data generation methods used in the experiment, the operationalization of deep processing, and the statistical analysis used to analyze the data. The four data generation methods are the self-report questionnaire, the log from the game prototype, the teacher feedback, and the argument graphs formed by the participants. Deep processing is measured by analyzing the argument graph each group of players created during gameplay. *Spearman's rank correlation coefficient* will be used to analyze relationships in the data.

22.1 Questionnaire

Participants of the experiment answered a questionnaire with 24 pre-defined questions. Questionnaires are commonly used in research because "they provide an efficient way of collecting data from many people" [9], which is useful in this research to get data on the participants and gain insight into their experiences with the game prototype. The 5 first questions are basic information questions and one question to fill in the unique ID of the participant. The remaining 19 questions are divided into 8 text questions, 5 Likert scale questions, 5 multiple choice questions, and 1 large Likert scale question with 16 sub-questions. The entire questionnaire can be found in Appendix G.

After the basic information section, the questionnaire is divided into five parts. Each of the five parts and their purpose for the research is described below.

22.1.1 Gaming and Interests

This section surveys the participants' gaming habits. The questions ask how much time the participant plays games, how many games they have played lately, and what kind of games they play. This section aims to get an idea of the participants' gaming habits, and the answers contribute to understanding who the participants are and how they relate to games.

22.1.2 Learning Approach in School

This section surveys the participants' learning approaches in school. As discussed in Chapter 10, 16 questions compiled by *Dan Murphey* [53] will be used as the operationalization of students' predispositions to learning approaches in a general school context. The questions from *Murphey* are a selection of questions from the larger *Learning Process Questionnaire* (LPQ) [53]. The researchers translated the questions into Norwegian; the exact formulation of the questions in Norwegian can be found in Appendix G. *Dan Murphey*'s adaptation was chosen due to its shortness compared to other versions of the LPQ. The answers to the questions can be used to calculate scores for each participant's learning approach in school. It gives two scores per student, one indicating their predisposition to utilizing deep approaches to learning in a general school context and the other indicating their predisposition to utilizing surface approaches to learning in a general school context. The scores calculated from the questionnaire can be used to compare the participants' predisposition to learning approaches in school to the degree to which their performance in the game indicates deep processing achieved by playing the game.

This section also has a question asking the participants to rate how much they enjoy the subject of history. Measuring this value reveals how the participants relate to the subject of history and can be used to understand the type of students participating in the experiment.

22.1.3 The Course of Gameplay

In the questionnaire, this section, called "Collective Reasoning", surveys the participants' experience with the gameplay and the gameplay session. One question asks how the group approached finding and maintaining information in the game. Another question asks how they approached the task of deciding what information to use in their argument graph and the structure of the argument graph. Finally, this section asks the participant what motivated them to play the game. The answers to these questions can be used to understand how the participants approached the game and what motivated them.

22.1.4 Evaluation of Collective Reasoning

This section asks the participants to evaluate the game. The section first asks how fun and easy to use the game was on a scale from 1 to 5. For each of these, the participant can also give a written explanation of their rating. This section also asks whether the participant would like to play the game again. The answers to these questions can be used to understand how the participants experienced the game and whether they found it enjoyable. By comparing the answers to the questions in this section to the participants' learning outcomes, it is possible to see if the participants' enjoyment of the game correlates with their learning outcomes.

22.1.5 Learning in Collective Reasoning

This section aims to survey the participants' learning in the game. The first question asks the student to rate on a scale from 1 to 5 how much they learned from the game. The next question asks the participant to briefly describe a concept they came across in the game that was new to them. The third question asks what sources the players learned from in the game. The last question asks the students to give an indicator for how long they will remember the knowledge attained while playing compared to traditional learning methods in school.

The answers to these questions can be used to understand whether the game successfully taught the participants new knowledge. The answer to the last question can be used to see the participants' perception of the lasting nature of the knowledge attained while playing the game, which is one of the three aspects of deep processing [1].

22.2 Teacher Feedback

Since the teachers are present and actively contributing as evaluators during the experiment, they can give helpful feedback on the game prototype and its use. The teachers are present in the classroom daily and have a lot of experience teaching history and teaching the specific group of students that participates in the experiment. This means that the teachers have a lot of knowledge about the students' learning and how the students usually behave in class. After the experiment, the teachers are asked to give feedback on the game prototype. In the context of this research, the teachers are *qualified observers*, functioning as *practitioner-researchers* [9], meaning they contribute as observers within their own professional context. The teachers are asked to give written feedback on the game prototype and highlight anything relevant. The teachers' feedback can be used to understand how well the game prototype worked in a classroom setting, which is essential for a *lecture game* like *Collective Reasoning*. Their insight can also be used to understand how the game may be improved in the future.

22.3 Argument Graphs as Measure for Deep Processing

The operationalization of deep processing is achieved through the analysis of the argument graphs. Each group in the game produces an argument graph, which the researchers observed and analyzed afterward. The argument graph is a representation of the result of the group's reasoning process and shows how the group presented and connected the concepts as part of the gameplay. Concepts are presented as nodes in the graph, meaning *facts* and *conclusions*, while the connections between the concepts are presented as *support relations*. An analysis of the argument graphs can be used to see how the groups approached the game and how they reasoned.

Since part of the focus in this thesis is on *deep processing*, the argument graphs will be analyzed to reveal whether they indicate that the participants have achieved deep processing. The definition presented previously of deep processing, in Chapter 10, is characterized by three aspects: (1) That one is learning concepts, methods, and connections between them, (2) the lasting nature of the understanding, and (3) the ability to utilize the understanding in new situations [1]. This analysis aims to ascertain the first and third aspects of deep processing. Given the short duration of the experiment and research project, the longevity of the learning outcome can not be measured. The knowledge that players pick up from course material or the internet must be dissected into basic concepts to fit into the argument graph; one way the players show that they understand the concepts is through this structuring. The players must then relate the concepts to each other – draw up and explain relations – to answer the unique session question; this answers the second part of the first aspect of deep processing. It also demonstrates that players can use the knowledge in a different context than where it was found, satisfying the third aspect of deep processing.

The *support relations* created represent the participants' understanding of the connection between different concepts, making the *support relations* a promising place to look for signs of deep processing. The *support relations* are meant to indicate that the nodes are connected in such a way that one node is backing the other node. To create an appropriate *support relation*, the participants must have an understanding of the concept in both nodes and the connection between them, meaning that a proper *support relation* is an indication that the participants have achieved deep processing. Criteria were established to determine whether a *support relation* indicates deep processing. The criteria were then used to assign points to each *support relation* in the argument graphs. The criteria are presented in Table 22.1, including IDs, how many points each criterion is worth, and a description of each criterion.

The five first criteria for *support relations* in Table 22.1 were developed a priori, representing varying degrees of understanding of the concepts and relations. A *support relation* falls in category **G0** if it is not discernable what concept the nodes represent. This means that the players have not understood the concepts well enough to demonstrate deep processing. **G1** indicates that the nodes represent tangible and unambiguous concepts, but that one concept does not support the other like a *support relation* should indicate. **G2** indicates that the participants have understood the concepts and that there is a support connection between them, but the support is too vague to be able to conclude that there has been deep processing. **G3** indicates that the participants represent the concepts well and that a strong and direct support connection exists between the concepts in question – a reasonable indicator for deep processing. The relationship, however, is not adequately explained in writing. **G4** indicates that the participants have understood the concepts and the connection between them, and they have conveyed the relationship in such a way that there is little room for doubt that there has been deep processing.

Table 22.1: Point table for support elation analysis.

ID	pts	Description
G0	0	The descriptions of the nodes are not tangible.
G1	0	The node at the tail of the relation does not support the node at the head.
G2	0	The node at the tail of the relation supports the node at the head, but it requires multiple unexplained leaps of thought to comprehend.
G3	0.5	The node at the tail of the relation supports the node at the head
G4	1	The node at the tail of the relation supports the node at the head, and the node descriptions include an explanation of the support relation between the nodes.
G5	NA	A support relation between equivalent nodes is made elsewhere in the graph.
G6	NA	The node in the relation descriptions present identical concepts.

The two last criteria in Table 22.1 were defined while conducting the analysis as a way to categorize relations that did not fit into the other categories. Both criteria result from an unexpected phenomenon: duplicate nodes – multiple nodes conveying the same concept. One possible explanation for why duplicate nodes might occur is a lack of coordination between group members; another is the difficulty of converting between facts and conclusions in the game. **G5** indicates that, because of duplicate nodes, the same connection exists and was rated between the same concepts elsewhere. It did not seem appropriate to give this relation any points, low or high, as they had received points for it earlier. Giving it no rating means it does not affect the average deep processing score. **G6** indicates that the head and tail nodes of a *support relation* were duplicate nodes of each other, and these relations were also not given any points. This anomaly suggests that the players struggle with the game mechanics, not processing the concepts in question. It is hard to imagine a player actually meant to create a support relation with this semantic meaning.

The points given to the relations can be used to understand to what degree the participants have achieved deep processing while playing the game. The points for all *support relations* in an argument graph can be summed up to get a total score for the group. The score functions as an indicator of how much deep processing has been achieved by the group in total. Calculating an average by dividing the score by the number of evaluated *support relations* gives insight into the accuracy of the *support relations* created by the group.

The result of the analysis is a number that serves as the operationalization of deep processing during the game and can be used to understand how the game facilitates deep processing. The result may be compared to the participants' predisposition for deep and surface approaches to learning or other player characteristics to locate factors that affect deep processing in the game.

22.4 Statistical Analysis

The only statistical analysis that will take place on the data gathered in this study is finding relationships between different variables. Two widely used statistical measures are *Pearson's product moment correlation coefficient*, used when the data is on an interval, and *Spearman's rank correlation coefficient*, used when the data is ordinal [9]. These two correlation coefficients use complex formulas to produce coefficients representing how related two variables are [9, 74]. Interval data can easily be converted to ordinal by sorting and giving an order. This project generates interval data, like deep processing score, and ordinal data, like game ratings on a Likert scale; therefore, ***Spearman's correlation coefficient*** is used for all correlation analysis. The *Spearman's correlation coefficient* is also more manageable in other ways, like not being disproportionally affected by outliers and not requiring that both variables are normally distributed [74].

With each *Spearman's correlation coefficient* calculated from the data, an associated p-value is also calculated. This p-value approximates the probability that the two underlying distributions of the variables would generate a *Spearman's correlation coefficient* at least as extreme if they were unrelated. This is achieved by calculating *Spearman's correlation coefficient* for a large number of random permutations of pairings between the two groups of samples – completely disregarding the actual relationship between the two while keeping the same numerical samples – and counting how many permutations ended up with the same or higher correlation. Tests such as this are called permutation tests of p-values [75, 76]. Since a random selection of permutations is used, the p-value calculated in this way only approximates the target probability. There is always a chance that the selected permutations do not represent the wider population. The number of permutations used in this study is usually 100000. Still, for some smaller sample groups, this is already more than all possible permutations; in these cases, all permutations will be factored exactly once, creating a much stronger p-value. If the p-value is beneath 0.05 (5%), the hypothesis that the distributions are uncorrelated is discarded.

22.5 Summary

This chapter presented four data-gathering methods used in this research and described the operationalization of deep processing by analyzing the argument graphs created during gameplay. The answers to the questionnaire and the analysis of the argument graphs both provide data that can be compared to each other in many ways to find patterns and connections between the data. The reasons are outlined for choosing *Spearman's rank correlation coefficient* for statistical analysis of relationships in the data, and the associated methodology has been presented.

23 | Reliability and Validity

This chapter will address reliability and validity concerns regarding the experiment and data generation methods used in the research. Reliability is the consistency of measurement, meaning that the results are generated using methods that are neutral, accurate, and reliable [9]. A piece of research has validity if an appropriate process has been used, the findings do indeed come from the data, and they do answer the research question [9].

23.1 The Experiment

This section will briefly look at internal and external validity concerns related to the conduction of the experiment and how they were addressed.

23.1.1 Internal Validity

The *internal validity* of a research project is related to knowing that the measurements obtained are due to the manipulations provided by the experiment, not any other factors [9]. This is a concern in this research project, as there is no control group to compare the results to, which could have been used to see if the results were due to the game or other factors. There is also no pre-test to compare the results to, which would have been a way to see if the results were due to the game or the players' prior knowledge. However, considering that the topics addressed in the session questions had not been covered in classes before the experiment, it is reasonable to assume that the players have minimal prior knowledge of the topic. Therefore, it is plausible to conclude that the observed indicators of deep processing in the argument graphs are an outcome of playing the game, as it is the only manipulation implemented in the experiment.

23.1.2 External Validity

External validity refers to the degree to which the result of an experiment is generalizable [9]. Methods for achieving high external validity include using participants that are representative of the population being studied and have representative test cases [9]. Since the students were recruited through their teachers, and the entire class participated, the test population testing the game is a relatively representative group of upper secondary school students. However, since all students were from two schools in the same city, the test population might not be representative of all upper secondary school students in Norway. The test cases were also representative of the game, as the session questions were on topics that the game is designed to be used for, and the game was played by students in their classrooms. However, the fact that the students were aware that they were participating in an experiment might have influenced their behavior, as they might have been more focused on the game than they would have been if they had played the game in a normal class. This is known as the *Hawthorne effect* and was likely present in our experiment [77]. Another concern is that the results may only be generalizable for the game *Collective Reasoning* or games very similar to it, not all learning games. The specific design of the game limits the generalizability of the results. The game concerns deep processing, and the results will likely be most applicable to other games concerning deep processing.

The teachers are likely not representative of the average teacher. There were only two teachers, and they volunteered to participate in the research, so it is possible that they are more interested in using games in their teaching than the average teacher. Due to the teachers being few and not likely representative, the results of the teachers' feedback should be interpreted with caution, which is why the teacher feedback is not used as a central part of the research, but rather as a supplement to the other data.

23.2 Data Generation

This section will look at reliability and validity concerns regarding two of the data generation methods used in the research. The log from the game is generated automatically by the game and does therefore not have any reliability concerns. The teachers' feedback is brief and allows the teachers, who are professionals within pedagogy, to elaborate on their answers, and their feedback is not essential or central to the research, so it is reasonable not to analyze reliability concerns regarding the teachers' feedback. The questionnaire, however, is a self-report questionnaire, which has some reliability concerns. The method used to analyze the argument graphs is also a concern, as it is a new method that has not been used before. The following sections will look at these concerns in more detail.

23.2.1 Questionnaire Concerns

Questionnaires are practical to use and result in data that is easy to analyze, but there are some reliability drawbacks to the data gathering method. Results from digital questionnaires can be automatically collected, reducing the risk of errors occurring with manual registration processes [78]. Further, the results are not dependent on an interviewer's interpretation of behavior, which may influence the results of an interview [78]. However, pre-defined questionnaire answers may not be exhaustive, and the participants may not be able to express their opinions in the questionnaire [9]. There is also no way to verify that the participants have understood the questions correctly, which may result in answers that are not relevant to the questions asked [9]. The questions asking the participant to rate from 1-5 are often followed by a question where the participant may elaborate on their answer, which can help reveal additional information regarding why the ratings are as they are. The questions were formulated to be as clear as possible.

The questionnaire is used to gather data on learning approaches using a standardized method, and not to gather data on the students' learning approach in the game, due to the reliability concerns regarding meta-meta-cognition. The Learning Approach Questionnaire by *Murphy* is a standardized method for gauging the degree to which students employ deep and surface approaches to learning [53], and has been used in research before [79], which makes it a reasonably reliable method for gathering data on learning approaches. As mentioned in Chapter 10, using self-report questionnaires to quantify deep and surface processing has been criticized because it requires meta-meta-cognition – thinking about one's thinking – which is susceptible to bias [42]. Therefore the choice was made not to develop a questionnaire to gather data on the students' learning approach in the game, but rather use a different method through analyzing their argument graphs.

Since the students are only surveyed once, right after playing the game, it is impossible to test the *longevity* of their learning in the questionnaire. Longevity is an element of deep processing, as presented by Udir [1], and should therefore ideally be tested to determine if the students have achieved deep processing. The questionnaire asks the students to rate how long they think they will remember what they have learned compared to if they had learned it in a traditional lesson, to try to determine the longevity. However, this is not a reliable method, as the students may be unable to predict how long they will remember the topic. A better solution would have been to test the students' knowledge of the topic at a later point in time, but this was not possible due to the time constraints of the research project.

23.2.2 Argument Graphs Analysis Concerns

Operationalization is the act of determining the measurement procedure of something that is not directly measurable, and the operationalization of deep processing is a concern in this research project, as the method used to analyze the argument graphs is a new method developed for this research. The method falls into the *type of measures* presented by *Dinsmore* and *Alexander* called *by condition* – by constructing a situation where the phenomenon is a precondition for certain outcomes [42]. As described in Chapter 22, the procedure aims to illuminate the parts of the definition of deep processing focused on "learning concepts, methods, and connections between them" and "the ability to utilize the understanding in new situations".

The main indicator – **validity of support relations** – for deep processing during gameplay in this research project results from analysis of the argument graph created by each group. Using a support relation correctly to connect two concepts shows that the players have processed the concepts and connections between them. On the other hand, making relations between concepts that are not connected in that way shows that the players do not understand the concepts or their connections. The method is time-consuming and susceptible to bias from the researchers, as they have to interpret the data. However, the method is based on the definition of deep processing and has been systematized (see Table 22.1) to the extent that it is utilizable in a procedure for analyzing the argument graphs. This makes it a reasonably reliable method.

23.3 Summary

There are multiple reliability and validity concerns addressed as part of the research in this project; some concerns are handled in accordance with best practices, and are therefore reliable, while others constitute a known possibility of risk to the reliability and validity of the research. Internal and external validity concerns are addressed by ensuring that the results are due to the game and not other factors, and that the results are generalizable. Reliability concerns regarding the questionnaire are addressed by allowing the students to elaborate on their answers, and the questionnaire is a standardized method for gathering data on learning approaches. The method used to analyze the argument graphs is a new method developed for this research, but it is based on the definition of deep processing and has been systematized to the extent that it is possible to create a procedure for analyzing the argument graphs. However, since the method has not been used before, the reliability of the method cannot be firmly established. Another concern is that the students are only surveyed once, right after playing the game, so it is impossible to test the longevity of their learning outcomes in a reliable way.

Part VII

Results

This part presents the results of the experiment. The results are presented in four chapters, the first three of which are based on one of the three data sources: the questionnaire, the argument graph analysis, and the teacher feedback. The fourth chapter compares the questionnaire and the graph analysis results. The results are presented descriptively using figures and tables where appropriate.

24 | Questionnaire Results

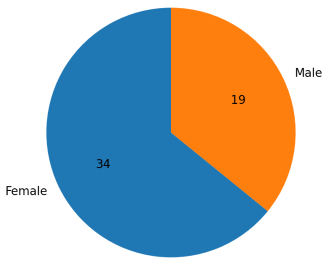
This chapter presents the results of the questionnaire. The questionnaire was distributed to the students after they had played the game. The questionnaire was distributed to 77 students in total, of whom 53 answered the questionnaire, which equals a response rate of 69%. Validity concerns regarding the response rate are addressed in Section 23.1.

24.1 Test Population Characteristics

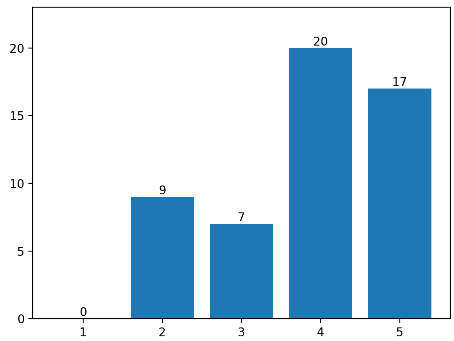
This section presents the general characteristics of the test population. All of the respondents were 17 or 18 years old.

24.1.1 Gender Distribution and History Subject Approval

Figure 24.1 shows gender distribution and history subject approval among the respondents. Figure 24.1a shows that 34 females and 19 males answered the questionnaire. Figure 24.1b shows to what degree the students like history as a subject in school. The students were asked to rate their approval of the history subject on a scale from 1 thumbs up to 5 thumbs up. The average rating of the history subject on a scale from 1 to 5 was 3.74. Overall, the students like history as a subject, as 70% of the respondents gave the subject 4 or 5 thumbs up, and no one gave the subject 1 thumbs up.



(a) Gender distribution.



(b) Approval of the history subject.

Figure 24.1: Questionnaire respondents' gender distribution and approval of the history subject.

24.1.2 Gaming Habits

Table 24.1 shows the distribution of gaming habits among the respondents. The respondents were asked how much they game on average per week and how many different games they have played in the last month. Both questions had intervals as answer options. The table shows the number of hours spent gaming per week on the X-axis and the number of unique games played in the last month on the Y-axis. The numbers in the table show the number of respondents who answered the questions with the corresponding answers. For example, 9 respondents answered that they game 0 hours per week and have played 0 unique games in the last month. The most frequent answer to both questions is 1-5, hours and games. Here, the questionnaire answer options could have been more precise, as someone who plays 30 minutes a week has no right option, and someone who plays five games a month has two options. This could have been solved by having more precise answer options. The lack of options may explain why three students said the game 0 hours a week, but have played 1-5 unique games in the last month.

Table 24.1: The distribution of gaming habits of questionnaire respondents.

		No. hours spent gaming per week					
		0	**1-5**	**5-10**	**10-20**	**20+**	**Total**
No. unique games played last month	**0**	9	3	2	0	0	**14**
	1-5	3	17	8	3	1	**32**
	5-10	0	0	0	2	2	**4**
	10-20	0	1	0	1	0	**2**
	20+	0	0	0	0	1	**1**
	Total	**12**	**21**	**10**	**6**	**4**	**53**

24.1.3 Approaches to Learning

Through the self-report questionnaire, questions by *Dan Murphy* were used to find the degree to which each participating student utilizes deep or surface approaches to learning [53]. A score for each of the learning approaches was calculated by summing the scores of the questions related to each approach and dividing the score by the number of questions, resulting in a score between 1 and 5, in accordance with the scoring of the original questionnaire [53, 79]. The score indicates the degree to which students employ deep and surface approaches to learning [79].

Figure 24.2 shows the distribution of the students' self-reported approaches to learning. A dark color on the dot in the scatter plot indicates that multiple dots are in the same spot because some students have received the same scores as each other along both axes. The average score for the deep approach to learning is 2.91, which is slightly lower than the average score for the surface approach to learning, which is 3.21.

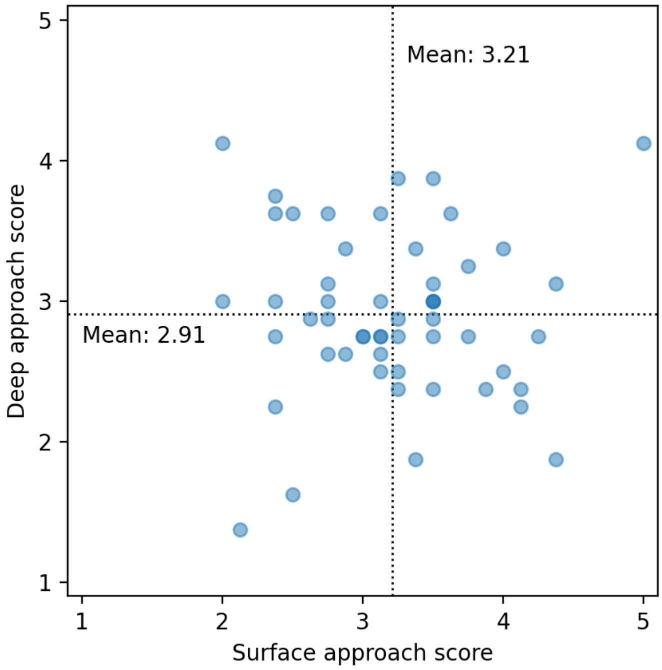


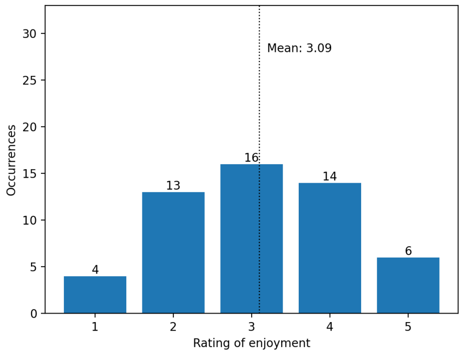
Figure 24.2: Participants' self-reported approaches to learning

24.2 Feedback on *Collective Reasoning*

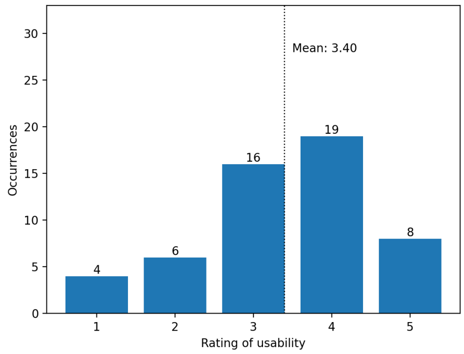
The questionnaire asked the students to give feedback on the game. The feedback was collected through Likert scales and checkbox questions. Many of the questions also had open-ended follow-up questions. The responses to these questions are presented in this section.

24.2.1 Numerical Ratings of *Collective Reasoning*

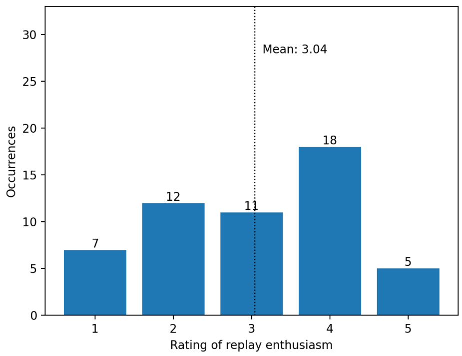
The players were asked to rate the game on a scale from 1 to 5, where 1 is the lowest and 5 is the highest, on five different dimensions: enjoyment, usability, enthusiasm for reusing the game in school, learning outcome, and longevity of learning outcome compared to a traditional lecture.



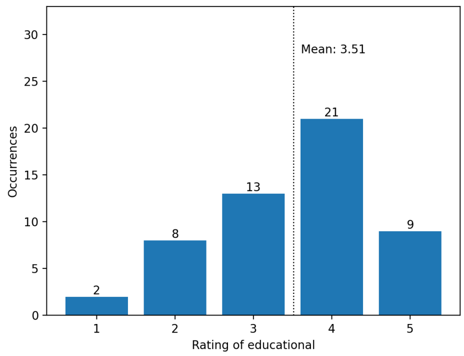
(a) Enjoyment.



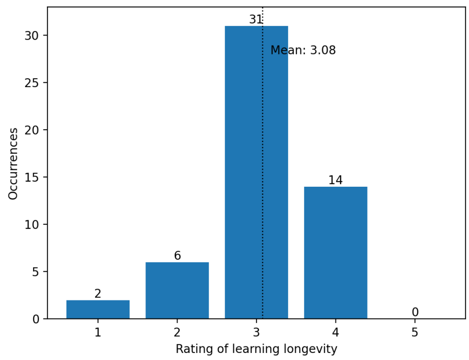
(b) Usability.



(c) Replay enthusiasm



(d) Learning outcome.



(e) Longevity of learning outcome compared to a traditional lecture.

Figure 24.3: Rating distributions for different aspects of the game

Figure 24.3 shows the respondent's ratings on each of the dimensions. The rating of the dimension (1-5) is along the X-axis, and the number of respondents giving each rating is along the Y-axis. Figure 24.3a shows that the average enjoyment rating was 3.09, and the responders' ratings almost follow a normal distribution bell curve. Figure 24.3b shows that the average usability rating was 3.40, and by reading the diagram, one can see that the median and mode rating is 4. Figure 24.3c shows the respondents' answers to the question "To what extent would you like to play the game again for learning purposes?", and the average answer was 3.04. Figure 24.3d shows how the respondents rated the game's learning outcome, and the average rating was 3.51, which is the highest average rating of all the dimensions. Figure 24.3e shows the respondents' answers to the question "How long do you think you will remember the knowledge you have acquired in this game compared to regular lecture?", and this question included an explanation of the numbers. 1 was "Much shorter", 2 was "shorter", 3 was "the same", 4 was "longer", and 5 was "much longer". The average rating was 3.08, which corresponds to “the same”. No one answered “much longer”.

The ratings of the game have been analyzed to look for statistical relations. As specified in Chapter 22, the *Spearman’s rank correlation coefficient* is used for this purpose. The coefficients and the associated *p*-values have been calculated between the answers from the five dimensions players rated the game, connected on each player. The results are presented in Table 24.2. With a sample size of 53 – the responses to the questionnaire – most pairings of dimensions seem to be statistically significant, meaning they have a *p*-value less than 0.05 and that the correlations are likely genuine. The only pairing that has a higher *p*-value is *Enjoyment* against *Learning outcome longevity*; here, the correlation is weak, which means that whatever correlation might exist itself acts more like the *null-hypothesis*, making them harder to separate. All dimensions of ratings are perfectly correlated with themselves. The strongest correlations are between (1) *Replay enthusiasm* and *Enjoyment* and (2) *Replay enthusiasm* and *Learning outcome*, with *Spearman’s correlation coefficients* of 0.716 and 0.758, respectively. The higher the correlation coefficients, the stronger the correlation, if it exists.

Table 24.2: Spearman’s rank correlation coefficients between game rating dimensions (left) and *p*-value of the no-correlation hypothesis (right).

	Enjoyment	**Usability**	**Replay enthusiasm**	**Learning outcome**	**Learning outcome longevity**
Enjoyment	1 | .00002				
Usability	.566 | .00004	1 | .00002			
Replay enthusiasm	.716 | .00002	.491 | .00020	1 | .00002		
Learning outcome	.606 | .00002	.588 | .00004	.758 | .00002	1 | .00002	
Learning outcome longevity	.219 | .11362	.408 | .00252	.217 | .00206	.421 | .00174	1 | .00002

24.2.2 Written Elaborations of Numerical Ratings

For each of the dimensions *enjoyment*, *usability*, and *learning outcome*, the questionnaire had a text field where the participants could comment on and elaborate on their answers on the Likert scales. The comments were analyzed and categorized into themes, which are presented in tables in the following sections. Only some of the comments are presented in the tables; they are selected to represent a holistic view of the feedback. The tables show the titles of categories in bold with colored backgrounds, and some of the comments in each category are presented below the titles. The color in the tables indicates the type of comments, green is positive, yellow is neutral or hard to categorize, and red is negative. The quotes are translated from Norwegian to English by the authors of this thesis. All the answers to the questions in Norwegian, as they were written, are in Appendix H.

Enjoyment

The participants’ comments on enjoyment are categorized into seven categories, three of which are positive, two are neutral, and two are negative. The comments are presented in Table 24.3. The positive categories are “competition”, “sense of accomplishment”, and “powerups”. The neutral categories are “took some time to understand the game” and “should have music”. The negative categories are “do not feel like a game” and “did not understand the point system”.

Table 24.3: Feedback on the enjoyment of the game.

E1	**Competition**
E1.1	Enjoyable that it was a bit stressful
E1.2	It was fun to compete, to work with others
E1.3	More fun: Competition, prize and deadline.
E1.4	I'm very competitive and that's what makes games fun for me.
E2	**Sense of accomplishment**
E2.1	It was a lot of fun when you saw that you got a good score on what was written because it gives you a small feeling of accomplishment.
E3	**Powerups**
E3.1	Powerups are cool
E6	**Took some time to understand the game**
E6.1	Didn't understand much of it at the start, took a while to get going.
E6.2	I think it was a lot of fun after a while when I understood it, very good :)))))))))
E7	**Should have music**
E7.1	Would have been cool with music in the background
E4	**Did not feel like a game**
E4.1	Feels it can't be called a game. A game should be fun. More of a mind map where we wrote things.
E4.2	Does not feel like a game when the game is based on the judgment of another human. It should have been AI if it rated all answers equally. Doesn't feel like a "game" in my eyes either, needs characters, but this is a learning game...
E4.3	It was a game about school subjects, so it automatically becomes more boring
E5	**Did not understand the point system**
E5.1	a bit difficult to know what to write to gain points. A bit stressful.
E5.2	The points system was, in its own way, a bit difficult to understand.

Usability

Table 24.4 shows the participants' comments on usability. There is only one positive category, not due to a lack of positive feedback, but because the positive feedback was very similar. The respondents also have negative feedback, categorized into three main categories. The negative categories are "disliked limitation of how many nodes can be edited", "confusing editing/evaluation process", and "Confusing to create argument graphs". No feedback used the term *argument graph*, but the feedback was categorized as such because it was about the process of creating the argument graph.

Table 24.4: Feedback on the usability of the game.

U1	**Usable and easy to understand**
U1.1	Simple and understandable buttons
U1.2	It was quite straightforward how to do the various things
U1.3	It was very clear what to do
U1.4	Easy to understand because not much happened

Continued on next page

Table 24.4: Feedback on the usability of the game. (Continued)

U2	**Disliked limitation of how many nodes can be edited**
U2.1	It was a bit annoying with a maximum of two unfinished fact boxes, this made it more difficult when working in larger groups, since everyone cannot work individually.
U2.2	A bit difficult that you could only have two unfinished facts at the same time because there were 5 of us in the group and then the others had to write in word while. I get it because it can get messy if there are five places that say "New fact".
U2.3	Could have been allowed to write down more facts at the same time
U2.4	It was a bit difficult that only two facts could be written at the same time and that you could not move the boxes' location. But otherwise it was not very difficult to use it once you had understood how it worked.
U3	**Confusing editing/evaluation process**
U3.1	We didn't understand that we couldn't change it once it was submitted.
U3.2	One could not edit the answer until they had received points and a rating on it. It made the game a bit difficult, and that was what took a lot of the points.
U3.3	I didn't understand much of the process of approval and editing.
U4	**Confusing to create argument graphs**
U4.1	A bit complicated and difficult to compose arguments in the way facts+conclusions
U4.2	confusing as to what the relation should be, but easy to enter information.

Learning Outcome

Table 24.5shows the participants' comments on the learning outcome of the game. The positive categories are "learning made fun by gameplay", "learning by collaboration", "learning from creating an argument graph", and "using their own sources". The negative categories are "only learn what they write themselves" and "negative time pressure".

Table 24.5: Feedback on the learning outcome of the game.

L1	**Learning made fun by gameplay**
L1.1	Easier to learn when it's something fun.
L1.2	It made learning much more fun, so that you wanted to learn more.
L1.3	You want to do well in the game and then you also pick up information more easily.
L2	**Learning by collaboration**
L2.1	When I get to talk to others about things, I learn more
L3	**Learning from creating an argument graph**
L3.1	It was a big mind map which is useful
L3.2	We had to read and understand the content in order to be able to write good answers

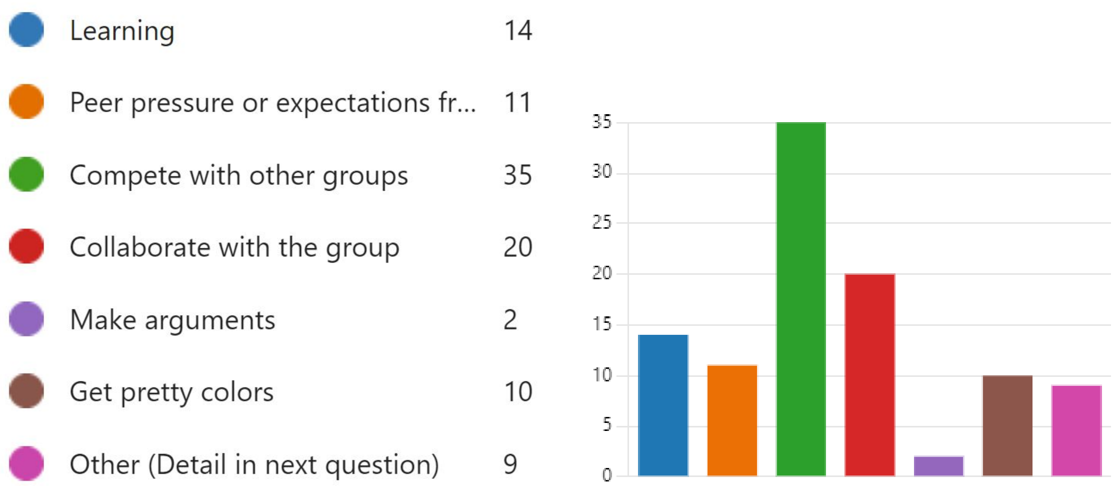
Continued on next page

Table 24.5: Feedback on the learning outcome of the game. (Continued)

L4	**Using their own sources**
L4.1	You do your own research on the topic.
L4.2	Found a lot of information that one would not otherwise have used or taken into account in such a simple question.
L5	**Only learn what they write themselves**
L5.1	I didn't write everything, so I don't have information about all the topics.
L5.2	You learn what you write yourself
L5.3	Since there are many of us, not everyone participates in all the boxes and thus does not learn everything that is included.
L5.4	The more people there are in the group, the more difficult it is to catch up on everything that is happening
L6	**Negative time pressure**
L6.1	The fact that we didn't have that much time meant that we didn't have the opportunity to think through everything as much and a more hasty conclusion was reached which meant that we didn't get to think and reflect as much.
L6.2	Can be a bit difficult to learn when the game has to be completed so quickly.
L6.3	Weird way to get information, through searching or looking considering that the game was timed put a little pressure.

24.2.3 Motivation Sources in the Game

The questionnaire asked the students to report what motivated them to play the game. The students could choose between 6 different motivation sources, and they could also choose "other" and specify what they meant. The respondents could choose up to three motivation sources. Figure 24.4 shows the distribution of the motivation sources. The most common motivation source was *competition*, which was chosen by 35 of the respondents. The second most common motivation source was *collaboration*, which was chosen by 20 of the respondents. The complete description of the orange option is not visible in the figure, but it was "Peer pressure or expectations from the group". Nine participants chose "other", and their elaborations are presented in the next paragraph.



(a) Color explanation. (b) Motivation source distribution.

Figure 24.4: Questionnaire respondents' reported motivation sources.

The nine participants who answered **"other"** were asked to specify what they meant, and their answers can be categorized into three Categories. Three of them said that they were motivated by **winning**, which can be viewed as a specific part of the *competition* motivation source. Three of them said that they were motivated by wanting to win **merchandise**. This is also related to the *competition* motivation source; however, the motivation source does not exist in the game alone. Two of them said that they simply played because they had to; they seemingly played due to **obligation** and mentioned no motivation source. One person just said "*History class*" as their motivation source, which we were not able to categorize.

Some of the respondents who chose specific categories also elaborated on their choice. Table 24.6 shows some elaborations that specify motivation beyond the categories. The colors in the leftmost column indicate what motivation source the elaboration is related to. M1 specifies that the player did not think about the fact that they learned anything until afterward and that they enjoyed the competition. M2 specifies that the player specifies that collaboration is a good tool for learning. M3 specifically said that the player has little competitive instinct and was mainly motivated by trying to do their best to meet the expectations of others.

Table 24.6: Elaboration on motivation sources.

	M1 I really enjoy competition, and to be completely honest, I didn't think about the fact that I actually learned anything until afterward. I really enjoyed this. I am also happy to come up with arguments that show that others are wrong and that I myself am right. I do team sports and think cooperation is a lot of fun. I want to do the best I can for the others.
	M2 Because it is a good tool for learning.
	M3 I have little competitive instinct, but try my best to meet the expectations of others.

24.3 Summary

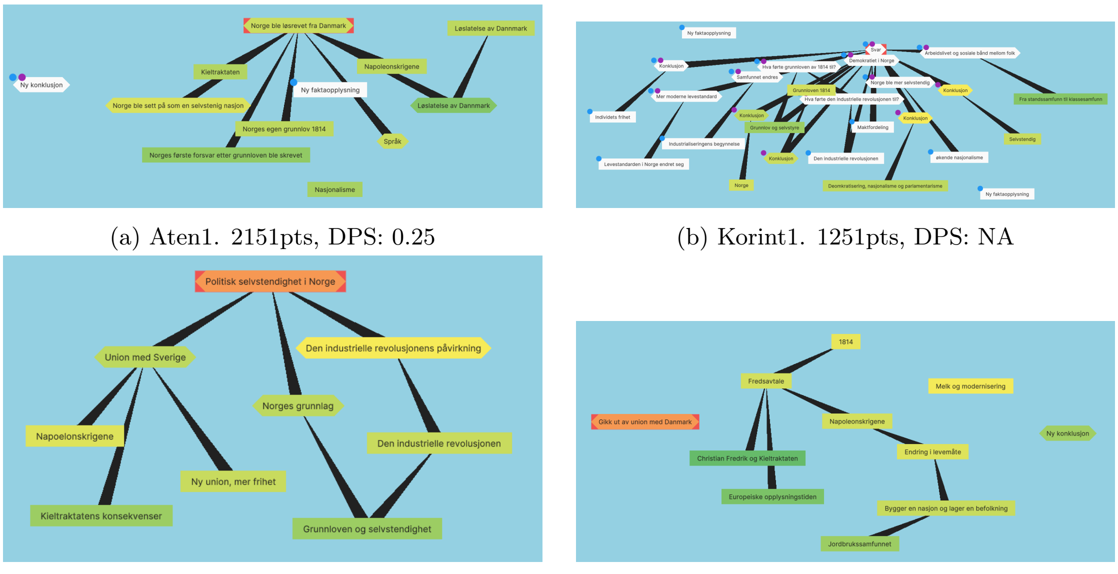
This chapter presented the results of the questionnaire. 19 males and 24 females answered the questionnaire, and most of them like the history subject. The students use a mix of deep and surface approaches to learning. The students rated the game *Collective Reasoning* on five dimensions, and the average rating was 3.09 for enjoyment, 3.40 for usability, 3.04 for replay enthusiasm, 3.51 for learning outcome, and 3.08 for the longevity of learning outcome compared to a traditional lecture. The game's ratings have been analyzed for correlation, showing that learning outcome and replay enthusiasm have the strongest correlation. The respondents gave written feedback on the game, both positive and negative. The most common motivation source in the game was reported to be *competition*, which 35 respondents chose.

25 | Argument Graph Analysis

The argument graphs were analyzed using the method described in Section 22.3. This chapter presents the argument graphs, deep processing scores from the analysis, and a comparison between the deep processing scores and game scores. The deep processing score of an argument graph is an average score for all relations in the graph, where each relation received a score between 0 and 1. The game score is the score the group received in the game based on ratings from the evaluators.

25.1 Argument Graph Analysis Score

The Argument graphs created by the players in the experiment are presented in Figure 25.1 and Figure 25.2. Each graph has the name of the group, a number (1-3) indicating which of the three experiments it is from, the game score the group got while playing (pts), and the deep processing score (DPS) in the caption. Appendix I shows the classification and scores of support relations, which are aggregated to create the deep processing score as detailed in Section 22.3.



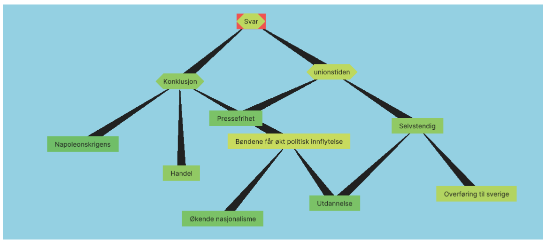
(a) Aten1. 2151pts, DPS: 0.25

(b) Korint1. 1251pts, DPS: NA

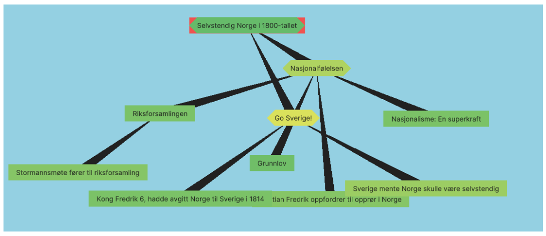
(c) Egina1. 1577pts, DPS: 0.50

(d) Sparta1. 1592pts, DPS: 0.14

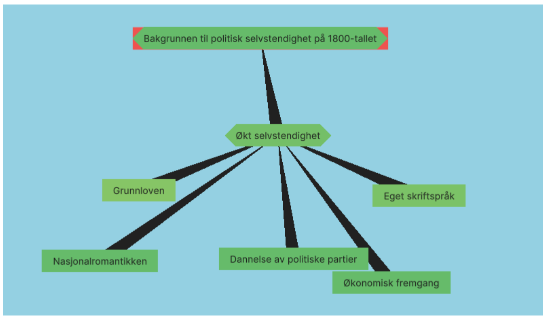
Figure 25.1: Graph analysis results. GA is the graph analysis score.



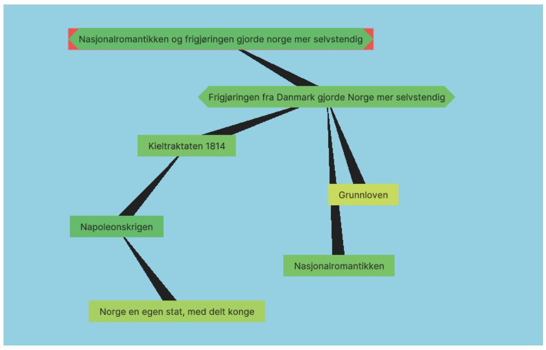
(a) Rodos1. 3013pts, DPS: 0.65



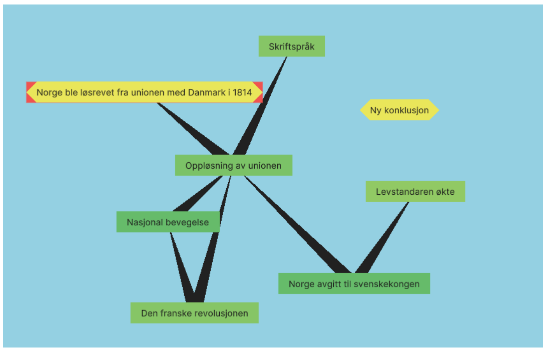
(b) Rodos2. 3294pts, DPS: 0.50



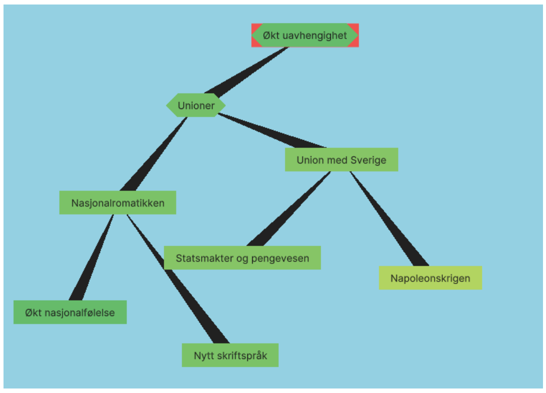
(c) Sparta2. 3453pts, DPS: 0.60



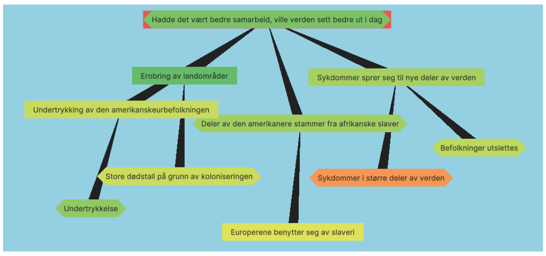
(d) Aten2. 2984pts, DPS: 0.60



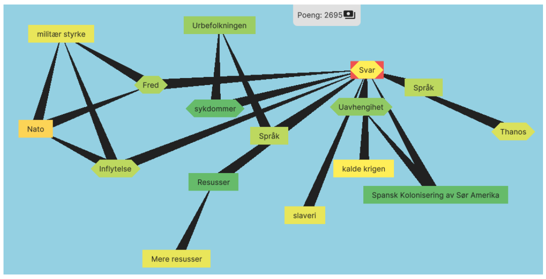
(e) Egina2. 2300pts. DPS: 0.42



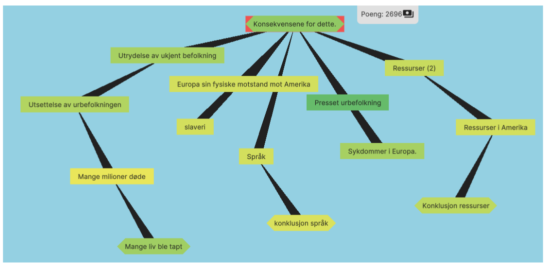
(f) Korint2. 3209pts, DPS: 0.42



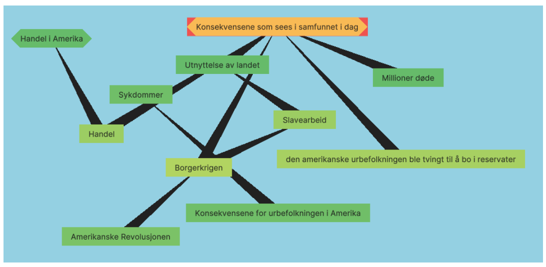
(g) Aten3. 2300pts, DPS: 0.43



(h) Egina3. 2695pts, DPS: 0.13



(i) Rodos3. 2696pts, DPS: 0.33



(j) Sparta3. 3675pts, DPS: 0.50

Figure 25.2: Graph analysis results. GA is the graph analysis score.

Figure 25.1 and Figure 25.2 shows that the argument graphs created by the groups are very different. Some groups have created graphs with a lot of nodes and support relations, like Egina3 (Figure 25.2h), while others have created graphs with fewer of both, like Korint2 (Figure 25.2f). Some graphs have a lot of width, due to many nodes linked to the same node, like Aten1 (Figure 25.1a), while others have a lot of depth, like Aten2 (Figure 25.2d). Most graphs are quite easy to read, but Egina3 (Figure 25.2h) is quite difficult to read, and Korint1 (Figure 25.1b) is very difficult to read due to a large number of nodes and relations. Many of the graphs have a lot more *facts* than *conclusions*, like Sparta2 (Figure 25.2c), while some have more of a balance between the number of *facts* and the number of *conclusions*, like Egina3 (Figure 25.2h).

Korint1 in Figure 25.1b is a special case, as it is the only graph where not all the nodes in the graph have been reviewed, and there is no deep processing score. While playing the game, Korint1 kept adding new nodes at a speed that made it impossible for the three reviewers to review all the nodes in the graph. Multiple attempts were made to ask the group to slow down, but they did not comply. A decision was made to stop reviewing their graph, to ensure that the other groups would get their graphs reviewed. The game score for the group is non-representative as it is based on a graph where most of the nodes were not reviewed. Since an analysis would have been very time-consuming, and would have been based on a graph where the players' had little chance to improve nodes from feedback, the graph analysis was not performed on their graph, which is why it says NA. The graph is included in the results as it resulted from playing the game in the experiment and is therefore relevant to the research. From here on out, Korint1 will be excluded from the analysis, but the case of Korint1 is discussed in the Section 28.4.

The game scores of the groups and the deep processing scores vary a lot between groups. The group with the lowest **game score**, Egina1, has a game score of 1577, while the group with the highest score, Sparta3, has a game score of 3675. The average game score is 2688, and the standard deviation is 645. The group with the lowest **deep processing score**, Egina3, has a deep processing score of 0.13, while the group with the highest score, Rodos1, has a deep processing score of 0.65. The deep processing score is 0.42, and the standard deviation is 0.161.

25.2 Comparison Between Deep Processing Score and Game Score

Figure 25.3 shows the deep processing score plotted against the game score for each group. The Pearson correlation coefficient is 0.517, and the p-value against the no-correlation hypothesis is 0.0705. This would indicate a moderate correlation between the deep processing score and the game score, but it is not statistically significant since the p-value is higher than 0.05. A reason it is not statistically significant could be that the sample size is too small, as there are only 13 groups.

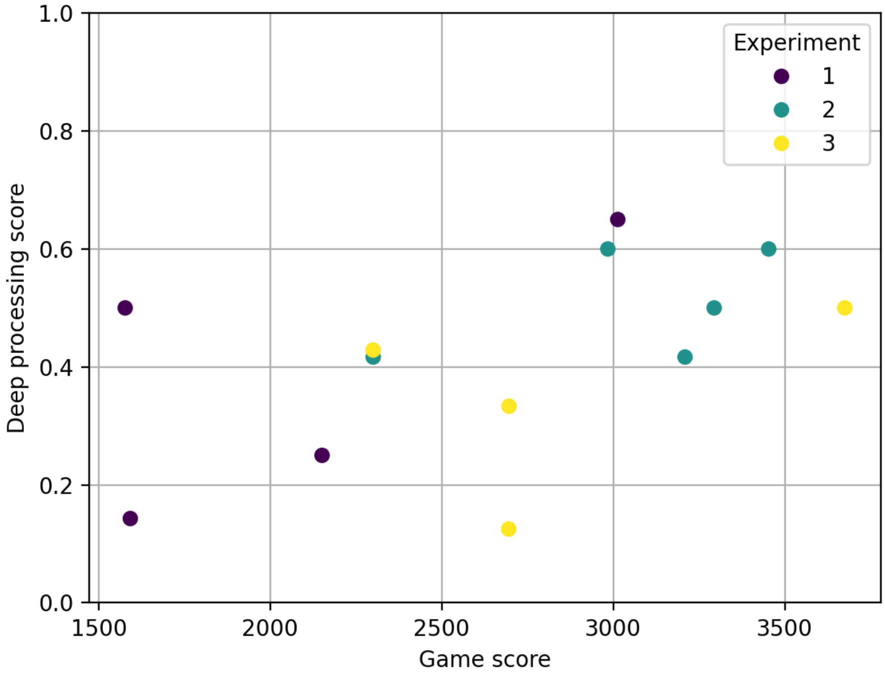


Figure 25.3: Deep Processing score from graph analysis per game score

25.3 Summary

This chapter has presented the argument graphs created by the groups in the experiment, the game score they were awarded, and the deep processing scores from the graph analysis. Game scores vary significantly between groups, from 1577 to 3675, and deep processing scores vary from 0.13 to 0.65 (range 0.00-1.00). One group was excluded from the analysis, as their graph was not reviewed due to the large number of nodes in the graph. The deep processing score and the game score have a moderate correlation, but it is not statistically significant.

26 | Teacher Feedback

The teachers were asked to give feedback on the game after the experiment. The feedback was originally given in Norwegian; the English translation is presented below. The feedback is presented in its entirety.

26.1 Teacher1, Experiments 1 and 2

Teacher1 participated in the first and second experiments. The feedback from Teacher1 was given by email. The teacher wrote the following:

> In general, I thought the game worked well and that a large part of the students had a good learning outcome. One thing that should perhaps have been changed was that it could be a bit confusing for the students to know what it was they hadn't done well enough when we gave a review (points). But I see perhaps the greatest benefit in the game as an opportunity for teachers to give a quick response to a draft of an assignment. I believe that many students would have benefited greatly from the game before they possibly had to start a larger project.

26.2 Teacher2, Experiment 3

Teacher2 participated in the third experiment. The feedback from Teacher2 was given by email. The teacher wrote the following:

> I think the game has potential. I observed that it motivated the students to work purposefully and exploratively with the history subject, which is desirable according to the new curriculum. With the game, they had the opportunity to practice this in a much shorter period of time than we usually operate with when we work in this way, and the competitive element contributed enough to the fact that several students who would normally have dragged their feet actually contributed. The game also helped cement understanding and use of subject terms such as hypothesis, cause, effect and source criticism.
>
> My only criticism of the game is the lack of clear instructions, but I think I may have reacted to this more than the students :D

26.3 Summary

The feedback we received on the game from the two involved teachers was both positive and negative. The feedback from both teachers mentioned that the game motivated the students to work with the history subject, and that the students seemed to have a learning outcome from the game *Collective Reasoning*. Teacher1 mentioned that the game could be confusing for the students and that it could be difficult for the students to know what they had done wrong when they were awarded low scores. Teacher2 mentioned that the game lacked clear instructions, but that this did not seem to be a big problem for the students. Both teachers mentioned that the game could be useful for teachers to give feedback to students on assignments. Further, Teacher 2 mentioned that the game could be helpful for students to practice working with the history subject and learn subject terms.

27 | Comparison of Results

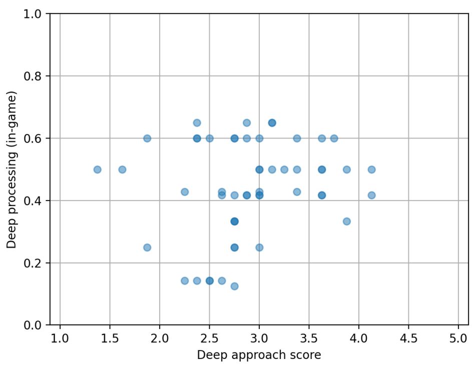
In this chapter, the results from the questionnaire and the argument graphs analysis are compared. The learning approach scores from the questionnaire are compared to the deep processing scores from the argument graphs analysis. This comparison is performed on both an individual and a group level. The motivation source results are also compared to the deep processing scores from the argument graphs analysis on a group level.

27.1 Deep Processing Score Compared to Learning Approaches

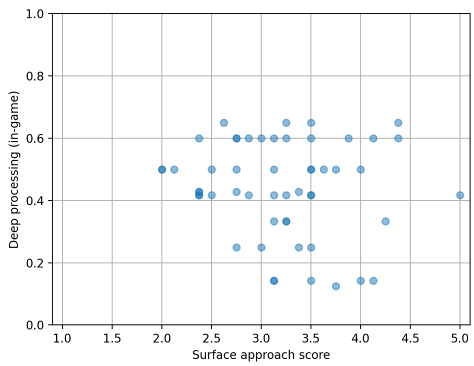
In this chapter, learning-approach data from the questionnaire and deep processing scores from the argument graphs analysis are compared to see if there are any correlations. Comparisons are made on both an individual and a group level.

27.1.1 Individual Level

Figure 27.1 shows each respondent's score on deep processing score and surface processing score from the questionnaire plotted against their group's deep processing score from the argument graphs analysis. Each dot represents one student, and all students who answered the questionnaire are included. The dots are slightly translucent, so the dots beneath representing players with identical scores are visible. Since the deep processing score from the graph analysis is on a group basis, many dots are on the same value on the y-axis. The processing approach scores on the x-axis are on an individual level. The figures show how the students are distributed on the two axes. No clear pattern emerges from the placement of the dots in either scatter plot.



(a) Deep processing.

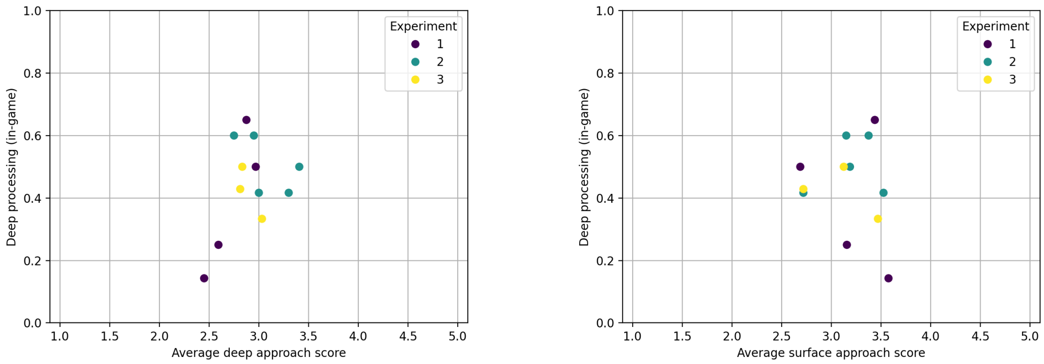


(b) Surface processing.

Figure 27.1: The learning approach scores of individuals plotted against the deep processing exhibited by their respective groups.

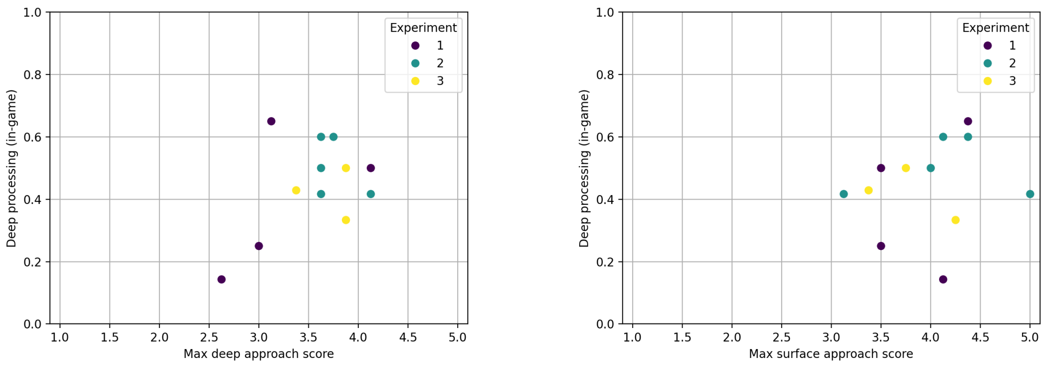
27.1.2 Group Level

Figure 27.2, Figure 27.3, and Figure 27.3 show the average, max, and lowest (min) learning approach scores of each group plotted against their deep processing score. Korint1 and Egina3 are not included in the plots. They had less than three group members answer the questionnaire, so their average, min, and max learning approach scores do not represent the group. In addition, no deep processing score could be calculated for Korint1.



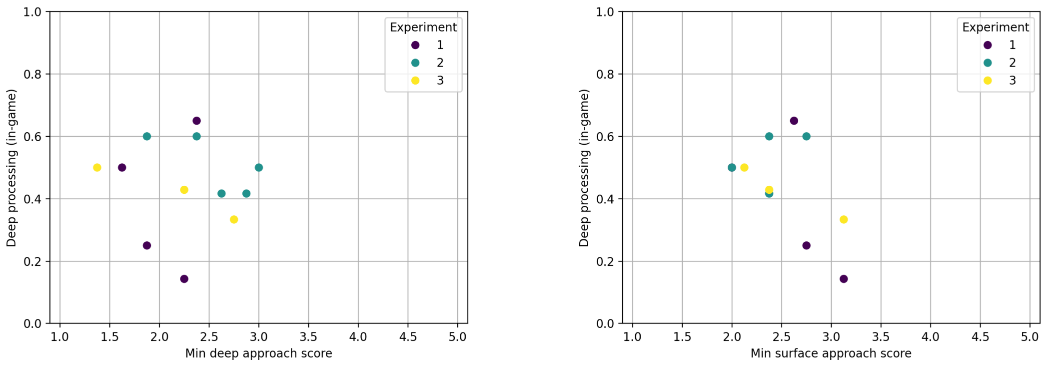
(a) Deep processing. (b) Surface processing.

Figure 27.2: The average learning approach scores of groups plotted against their deep processing score.



(a) Deep processing. (b) Surface processing.

Figure 27.3: The max learning approach scores of groups plotted against their deep processing score.



(a) Deep processing.

(b) Surface processing.

Figure 27.4: The lowest (min) learning approach scores of groups plotted against their deep processing score.

No obvious pattern emerges in any of the plots, but some dots in some plots stand out. In Figure 27.2a, the two groups with the lowest average deep approach score also have the lowest deep processing score (which is Aten1 and Sparta1), and they are somewhat separate from the cluster of other dots. The same two groups also stand out in the same way in Figure 27.3a, which shows the respondent with the highest deep approach score in the group instead of average, but not in Figure 27.4a, which shows the respondent with the lowest deep approach score in the group. No such pattern is visible in the surface approach plots.

27.1.3 Correlation Analysis

The correlation between different measures of learning approaches of groups and individuals and their deep processing score was assessed with *Spearman's rank correlation coefficient*. The deep processing scores are compared to **eight** different series: Two (1,2) are the learning approach scores of the individuals in the group that attained each respective deep processing score, and six are different aggregations of learning approach scores. One aggregation averages the learning approach scores of players in a group to get a representation of the learning approach scores of the group (3, 4). The two other aggregations work in a similar manner, but instead of an average, the highest (5, 6) and lowest (7, 8) learning approach scores among players represent the group. The coefficients and p-values are presented in Table 27.1. The analysis does not reveal any statistically significant relationships in the data, as the p-value is consistently way above 0.05; in other words, the deep processing score of a group seems to not be correlated with any of the measures of the learning approach scores, neither the aggregations nor individual learning approach scores. The sample size of groups with both learning approach scores and a deep processing score is only 12, so finding correlations was always going to be difficult. However, the correlation coefficients are also generally very weak.

Table 27.1: *Spearman's rank correlation coefficients* of the different learning approach measures and exhibited deep processing, and p-values against the no-correlation hypothesis.

	Spearman's rank correlation coefficients	***p*-value**
Individual DA	0.185	0.183
Individual SA	-0.082	0.557
Group DA (average)	0.134	0.676
Group SA (average)	-0.260	0.412

Continued on next page

Table 27.1: *Spearman's rank correlation coefficients* of the different learning approach measures and exhibited deep processing, and p-values against the no-correlation hypothesis. (Continued)

Group DA (max)	0.202	0.526
Group SA (max)	0.256	0.419
Group DA (min)	-0.114	0.719
Group SA (min)	-0.420	0.176

Terms: *DA* means "deep approach", and *SA* means "surface approach"

27.2 Motivation Source per Deep Processing Score

Table 27.2 shows the deep processing score from the graph analysis and the distribution of motivation sources for all groups. The groups are sorted by their deep processing score in descending order. The three motivation sources categories identified among the players who answered "other" have been added; they are "Winning", "Merchandise" and "Obligation".

The values for each motivation source in Table 27.2 indicate how many of the groups' respondents have selected each motivation source. A value of 0.50 for a motivation source means that half of the respondents in the group have selected that motivation source. The colors' opacity represents the motivation source's value, where a darker color means a higher value.

Table 27.2: Deep processing of groups compared against group members' frequency of different motivation sources.

Group name	**Deep processing score**	**Learning**	**Peer pressure**	**Competition**	**Collaboration**	**Make arguments**	**Get pretty colors**	**Winning**	**Merchandise**	**Obligation**
Rodos1	0.65	0.00	0.00	0.75	0.25	0.00	0.25	0.00	0.25	0.00
Aten2	0.60	0.17	0.00	0.83	0.17	0.17	0.50	0.17	0.00	0.00
Sparta2	0.60	0.20	0.00	1.00	0.40	0.00	0.00	0.20	0.20	0.00
Egina1	0.50	0.00	0.50	0.75	0.50	0.00	0.25	0.00	0.25	0.00
Rodos2	0.50	0.25	0.75	0.50	0.50	0.25	0.00	0.00	0.00	0.00
Sparta3	0.50	0.33	0.33	0.67	0.67	0.00	0.33	0.00	0.00	0.00
Aten3	0.43	0.25	0.25	0.75	0.50	0.00	0.00	0.00	0.00	0.00
Egina2	0.42	0.75	0.25	0.50	0.25	0.00	0.50	0.25	0.00	0.00
Korint2	0.42	0.40	0.20	0.40	0.60	0.00	0.00	0.00	0.00	0.00
Rodos3	0.33	0.50	0.50	0.25	0.25	0.00	0.00	0.00	0.00	0.00
Aten1	0.25	0.00	0.00	1.00	0.25	0.00	0.25	0.00	0.00	0.00
Sparta1	0.14	0.40	0.00	0.60	0.40	0.00	0.20	0.00	0.00	0.20

Some color patterns in Table 27.2 stand out. The green color of **competition** mostly fades downwards in parallel with the deep processing score until the two bottom rows. Spearman's rank correlation coefficient was calculated to see if there is a correlation between deep processing score and competition as a motivation source. The correlation coefficient was 0.418, and the p-value was 0.173. The correlation is not statistically significant. The blue color of **learning** almost fades upwards, opposite the deep processing score. The orange color of **peer pressure** is not present in the top-most and bottom-most rows. The red color of **collaboration** is present in all groups, but no pattern is visible. All groups motivated by **merchandise** got a high deep processing score. The only group that reported **obligation** as a "motivation source" was Sparta1, and they had the lowest deep processing score. The other colors are all mostly weak and scattered.

27.3 Summary

This chapter compared the deep processing scores to the results from the questionnaire. The learning approach scores of groups and individuals were compared to the deep processing scores. The plots did not reveal any apparent patterns, and the analysis did not reveal any statistically significant correlations between the two. A table showing each group's deep processing score and motivation sources indicated that there could be a relationship between the deep processing score and the motivation source of competition. Further, the correlation was calculated and found to be 0.418, but it was not statistically significant.

Part VIII

Reflection and Conclusion

This part discusses the results, their implications, and the research project. Chapter 28 discusses the results in the context of the research goal and questions and their validity. The conclusion in Chapter 29 summarizes the findings and implications. Chapter 30 contains some comments and reflections on this master project by the researchers, and Chapter 31 puts forth some directions in which the work of this project can be continued, both for research purposes and societal value.

28 | Discussion

The purpose of the project was defined by four research questions (RQs). This chapter presents reflections regarding each research question and elaborates on how the RQs have been answered as part of this project. Lastly, the chapter discusses the validity of the results.

28.1 Research Question 1

How can a lecture game motivate learning?

This research question deals with a central part of the goal of the *game-based learning* method, namely using games to encourage and motivate students to participate in learning while playing [11]. Elements from different theories of enjoyment in games [34, 35, 37] were incorporated into the game design of *Collective Reasoning*. To answer research question 1, it is reasonable to look at how the students experienced the game with regards to motivation, enjoyment, and learning. To generalize the findings, it is also relevant to look at how the students' experiences with the game design align with the theories of enjoyment, and look at the game design from a broader perspective, including what our findings mean for the game design of lecture games in general.

The **reviews on the enjoyment** of *Collective Reasoning* from the questionnaire are not very positive. The game received a rating of 3.09 on a scale from 1 to 5, and the diagram creates a bell curve around 3, which is the middle alternative. Getting an average rating so close to the middle alternative is not great, considering that making learning fun by using games is central to game-based learning [11]. Negative comments on the enjoyment of the game emphasize that some respondents think *Collective Reasoning* did not feel like a game, and that they did not understand the point system in the game. The following section discusses what game design elements the students did and did not enjoy, and how their feedback aligns with enjoyment theories.

28.1.1 Enjoyment and Motivation in *Collective Reasoning*

The **lack of fantasy and curiosity** are aspects of the game that are not in line with *Malone*'s theories of enjoyment. *Malone* emphasized that fantasy is an important part of making games interesting, and fantasy refers to showing or evoking images of objects or situations that are not present [34]. *Collective Reasoning* has colors and confetti, but that is not enough to say that the situation of creating an argument graph is placed in a fantasy. One student expresses that *Collective Reasoning* " [...] doesn't feel like a "game" in my eyes either, needs characters, but this is a learning game " (E4.1), which is a reference to the lack of fantasy since adding characters could be a way of implementing fantasy. Curiosity is a strong desire to know or learn something, and it can be evoked by providing an environment with an ideal level of complexity that the players can explore [34]. *Collective reasoning* does not have a complex or stimulating game world, which is why it does not evoke curiosity. Placing the game in a fantasy and making the game world more complex are both aspects of the game that would likely have made it more enjoyable, as stated by the theories of enjoyment and the students.

The **unintuitive game score system** is an aspect of the game that is not in line with *Sweetser* and *Wyeth*'s theory of GameFlow [35] and is a sign of a suboptimal game reward system [37]. One student states that "The points system was, in its own way, a bit difficult to understand" (E5.2), which makes it clear that the point system was not intuitive. The lack of transparency and information about the point system makes it hard for the player to develop *player skills* [35], as the points might feel random and unfair. A player might feel like they improved a *fact* in the graph, but still get the same rating as before, because they did not understand why they got deducted points. This is not in line with GameFlow theory, which emphasizes that the players should be able to develop *player skill* [35]. *Wang* and *Sun* point out that a game reward system should be balanced, so that the award received is proportional to the effort spent [37]. Players can feel as though that is not the case when they are not provided an explanation of the point system in *Collective Reasoning*. A more intuitive point system would likely have made the game more enjoyable.

On the other hand, the way **challenge** was incorporated into the game was well-received by the students. ***Competition*** *with other groups* was the motivation source with the highest rating from the questionnaire, and multiple students commented that competition was what made the game enjoyable for them. The comment "I really enjoy competition, and to be completely honest, I didn't think about the fact that I actually learned anything until afterward [...]" (M1) indicates that competition was a motivation source that worked well in the game. The fact competition was what made the game enjoyable for a lot of students affirms that the reward mechanism of points worked well for social purposes, as described by *Wang* and *Sun* [37], and contributed to the players' ability to achieve GameFlow through social interaction and challenge [35]. The comment "It was a lot of fun when you saw that you got a good score on what was written because it gives you a small feeling of accomplishment." (E2.1) handles another aspect of the challenge element, as the statement indicates that the game aligns with how *Malone* describes that a challenge should engage players' **self-esteem** by providing goals [34]. It is worth noting that not all players are motivated by competition, as stated in the comment "I have little competitive instinct, but try my best to meet the expectations of others" (M3). Even though the challenge element was seemingly well implemented in *Collective Reasoning* in the form of competition, as it was mentioned as an enjoyable aspect by many students, it is important to remember that not all students are motivated by competition and that other motivation sources should be considered when designing learning games.

It seems like some students experienced **GameFlow**, while others did not [35]. The comment "[...] to be completely honest, I didn't think about the fact that I actually learned anything until afterward [...]" (M1) contains indications that the student who wrote this experienced GameFlow, as the student was so immersed in the game that they did not think about other things [35]. For this particular student, the elements in the game were well-balanced, and the game was enjoyable. The game was less enjoyable for other students, like the student who expressed "Feels it cannot be called a game. A game should be fun. More of a mind map where we wrote things" (E4.1), who did not experience GameFlow. Elements that possibly block some players from experiencing GameFlow include hindered *player skill* development, as discussed earlier, and the fact that the players must seek information and knowledge outside of the game, which can hinder immersion [35].

28.1.2 Enjoyment, Learning, and Replay Enthusiasm Correlation

Strong and statistically significant correlations are reported between enjoyment, learning outcome, and replay enthusiasm in *Collective Reasoning*. Learning outcome is the dimension that got the highest rating from the students, with an average of 3.51. Both teachers also pointed out that it seemed like the students learned a lot; teacher1 said "I thought the game worked well and that a large part of the students had a good learning outcome" and teacher2 said "I observed that it motivated the students to work purposefully and exploratively with the history subject". The correlation between enjoyment and learning outcomes reported by the questionnaire is 0.606, which is a strong correlation, and the p-value is 0.00002, meaning the correlation is statistically significant. Based on this result, there is no way to know whether enjoyment leads to learning or learning leads to enjoyment in the game, but it is natural to assume that there is a combination of both, meaning learning leads to fun and fun leads to learning in learning games. Learning and fun being highly correlated align with *Malone*'s view on fun and learning in learning games [34]. There is also a strong correlation between replay enthusiasm – the keenness to use the game again – and both learning and enjoyment. The correlation between learning outcome and replay enthusiasm is 0.758, and the correlation between enjoyment and replay enthusiasm is 0.716, both with very low p-values. This correlation emphasizes the importance of enjoyment and learning outcomes; without it, the players will not want to play a learning game again, which makes sense since they have not gained anything from the game.

28.1.3 Summary

It is clear that the results from testing the lecture game *Collective Reasoning* in experiments align with existing theories of enjoyment in games. The theories of enjoyment that are successfully implemented, such as challenge and social interaction, work well in the game, but the fact that some elements of enjoyment are missing from the game, such as fantasy and curiosity, hinders the game from being enjoyable to more players. Lecture games seem to be fundamentally similar to other learning games in the sense of what makes them enjoyable. A strong correlation between replay enthusiasm and both learning outcome and enjoyment indicates that both learning outcome and enjoyment are important for the players to want to play the game again. This makes sense, since players derive little benefit from a game if they have not gained anything substantial from it.

28.2 Research Question 2

How can a lecture game facilitate deep processing?

Specific techniques were used to facilitate deep processing in *Collective Reasoning*. The two most important are (1) the building of argument graphs and (2) the self-guided and exploring nature of the information gathering. This section will analyze and discuss these techniques and their usage in *Collective Reasoning*. The influence of deep processing on game concepts is also discussed.

28.2.1 Argument Graphs in Learning Games

The breakdown of **argument graphs** into constituents – *facts*, *conclusions*, and *support relations* – means the players have to work with representations of concepts in the subject of study and the relations between them. Some comments among the written elaboration of players' rating of the *learning outcome* indicate that constructing an argument graph helps facilitate deep processing, namely the comments "It was a big mind map which is useful" (L3.1) and "We had to read and understand the content in order to be able to write good answers" (L3.2). Previous research into argument graphs as a replacement for traditional note-taking, albeit not in a learning game context, is also positive with regards to fostering learners' ability to contemplate the connections between arguments and express these connections explicitly [51].

On the other hand, some comments among the written elaborations of players' rating of the *usability* of the game indicated that the **usability challenges** from tying argument graphs into gameplay, or at least the specific execution of this in *Collective reasoning*, are substantial. The comments in U4.1 and U4.2, U4.2 being "confusing as to what the relation should be, but easy to enter information.", indicate that it was hard to understand the conceptual model developed around the argument graph in *Collective Reasoning*. The comments in U2.1 through to U2.4, U2.2 being "A bit difficult that you could only have two unfinished facts at the same time because there were 5 of us in the group and then the others had to write in word while. I get it because it can get messy if there are five places that say "New fact".", complain about the difficulty of working with the limitations imposed on the construction of the argument graph. These limitations, like the one mentioned in U2.2, were implemented to make the argument graph manageable for all participants – players and evaluators. The comments in U3.1 through to U3.3, U3.3 being "We didn't understand that we couldn't change it once it was submitted.", complains about the editing and evaluation process of the constituents in argument graphs. Although these problems are design problems that can be solved, a considerable amount of work was dedicated to making interactions with the argument graphs frictionless. Overall, the *usability* rating has the second highest rated average among the five dimensions sampled, at 3.40, so the usability of the game as a whole is good. The still prevalent sentiment that there are usability problems with the argument graph indicates that care and mindfulness are needed to integrate the concept of argument graphs into interactive experiences and learning games, though promising for achieving deep processing.

28.2.2 Nature of Information Gathering

The **self-guided** and **exploring** nature of the **information gathering** is designed to facilitate deep processing. The game prompts players to answer a very particular question in a large field, and the player has the freedom to craft individualized arguments to answer this question. Information from sources must be comprehended to evaluate the relevance of the information to the session question and the player's current argument or argument graph. The comments in L4.1 and L4.2, L4.2 being "Found a lot of information that one would not otherwise have used or taken into account in such a simple question.", support this line of thought. However, the comments in L5.1 through to L5.4, L5.3 being "Since there are many of us, not everyone participates in all the boxes and thus does not learn everything that is included.", complain that a player only gets an intimate understanding of the concepts and relations they themselves found, comprehended, and formulated. On the one hand, this coincides well with the understanding of deep processing developed from the preliminary study – that relating new information to the argument graphs is a central part of what facilitates deep processing. On the other, it indicates that the **group sizes** used in *Collective Reasoning*, around **five**, are **too large** or that not enough is done to enforce or incentivize *deeper cooperation* between group members during information gathering, hampering players' ability to understand the whole argument graph of the group and, therefore, their ability to even relate new knowledge to the group's argument graph.

28.2.3 Deep Processing in Learning Games

Incorporating the concept of deep processing into a learning game places substantial limitations on the game concept, especially if the game should have *flexible learning content*. It was decided that *Collective Reasoning* should have a *flexible learning content* to maximize the number of learning situations where the game can be applied. This means that the learning content of the game can be adjusted; it is described further in Section 6.3. The game is supposed to facilitate deep processing; it follows from the definition of deep processing [1] that the concepts and relations between them from the subject to which the learning game is being adapted must be included in the game in some way. Furthermore, since the subject changes from class to class, the concepts are essentially arbitrary, and their common representation format must remain abstract, like *facts* and *conclusions* in *Collective Reasoning* do. It is infeasible to encode concepts in more concrete ways for each subject ahead of time, since the unpredictable direction of information gathering and arguments is inherently part of deep processing; the whole world's knowledge base cannot possibly be included. In conclusion, the game must be based on abstract representations of concepts and relations from the subject, analogous to *facts*, *conclusions*, and *support relations* in *Collective Reasoning*. This places substantial limitations on the types of games that can even be learning games that facilitate deep processing in terms of genre, fantasy elements, goals, etc. It is, however, not strictly necessary that the players construct argument graphs. This extension of the abstract representations is implemented in *Collective Reasoning* to force the players to utilize the information gathered in a new situation, tackling one of the aspects of the definition of deep processing – that learners should be able to use the knowledge attained in new situations [1]. It is conceivable that a different type of gameplay can be designed fulfilling the same need.

28.2.4 Summary

Different techniques and concerns around facilitating deep processing in learning games have been addressed. The implementation of **argument graphs** in *Collective Reasoning* shows the potential of the technique to facilitate deep processing, but introduces considerable usability design challenges, like communicating the meaning of different elements of argument graphs. Purposeful but **self-guided exploration of information** in a subject also facilitates deep processing. However, when implementing this technique, one must not forget that players who do not participate in finding and repurposing information have not yet processed the information deeply, which should be mitigated through the design of player interaction and gameplay organization, for example, group sizes. In general, gameplay that should facilitate deep processing of an arbitrary subject has to be based on **game elements that can encode arbitrary information**, a severe limitation on game design.

28.3 Research Question 3

What are the characteristics of the deep processing facilitated by the developed lecture game?

This section discusses whether deep processing during the gameplay can be ascertained, what effects the game context can have on measuring deep processing, and the relationship between learning approaches and deep processing.

28.3.1 Ascertaining Deep Processing

The results from the analysis of the argument graphs created by the students in the experiments indicate that deep processing took place. Nine groups (62%) got a deep processing score above 0.4. The deep processing score for a group is a result of the researchers analyzing each support relation in the group's argument graph. A group can achieve a score of 0.4 by having mostly precisely formulated *facts* and *conclusions* and, for example, having either 40% of their support relations being valid and explained or 80% being valid but not well explained. A more likely scenario for a group with a score of 0.4 is that their argument graph is somewhere in-between, and consists of a mix of well-explained and not-well-explained valid support relations. We argue that almost every support relation that contributed positively to a group's deep processing score confirms an instance where deep processing happened. A support relation contributing to the deep processing score indicates that the group has learned two concepts and the relations between them, and has utilized the knowledge in a different context from that which the information originated.

Many factors likely contributed to reducing the deep processing score of the groups. In the players' feedback on the *learning outcome* of the game in the questionnaire, some players indicate that **time pressure** got in the way of deliberating over the details of their argument graph. Comments on time pressure include L6.1-L6.3, where L6.1 states "The fact that we didn't have that much time meant that we didn't have the opportunity to think through everything as much and a more hasty conclusion was reached which meant that we didn't get to think and reflect as much". As discussed in Section 28.4, the scoring mechanism related to *support relations* was not very transparent to players during gameplay. This could lead to players being **unconcerned with the state of their *support relations***, as they are unaware of its effect on the score, which is first factored in after the game is finished. The argument graph is shared among the entire group, but how much deep processing each member of a group experiences during gameplay likely varies, and some players might not communicate their deep processing to the rest of the group; if this is the case, it is to be expected that **not all players are able to add *support relations*** in a way indicating deep processing. In light of these three concerns, a deep processing score of 0.65, the highest observed, and even 0.42, the lowest over 0.4, is even more significant.

The deep processing score is the method used to operationalize the deep processing performed by players during gameplay, but it does not consider the longevity of the learning outcome. Learning longevity is one of the aspects of the definition of deep processing [1]. A question in the self-report questionnaire was used to gauge learning longevity by asking the respondents how long they thought they would remember what they learned from the game compared to how long they would remember from a normal learning activity. The question does not differentiate between the learning outcome related to the subject or to the skill of reasoning. The average rating of learning longevity is 3.08 (see Figure 24.3e), just above the middle option, and the answers are heavily centered around the middle option. As described in the questionnaire, the middle option indicates that the learning longevity is similar to normal learning activities. Given its somewhat vague connection to the rest of the deep processing score, this result does not contribute much to confirming deep processing during gameplay. However, it is reassuring that it is not inexplicably low.

28.3.2 Measuring Deep Processing

Out of the six *types of measures* found by *Dinsmore* and *Alexander* in deep processing literature [42], this study has utilized *by condition*. Measuring *by condition* is done by constructing a situation where the phenomenon is a precondition for certain outcomes [42]. This was a common *type of measure*, accounting for 28.3% of the studies analyzed by *Dinsmore* and *Alexander* [42]. Measuring deep processing *by condition* should be easier in video game environments than in other scenarios, because video games are inherently controlled and quantified. Events, statistics, and other quantitative data from a video game environment can easily be logged during gameplay, giving more opportunities when designing measurements *by condition*.

The deep processing score measure (see Section 22.3) fits most aspects of the definition of deep processing well, except for *longevity of learning outcome*. This is likely made possible by the *facts*, *conclusions*, and *support relations* being available to the researchers with little effort.

28.3.3 Effect of Learning Approaches on Deep Processing

One important relationship that warrants discussion is the connection between learning approaches [49, 53] and deep processing [1, 42]. Utilizing *Collective Reasoning* will not have achieved much if the extent to which a player normally uses a deep approach to learning explains all the deep processing that occurred in the game. In that case, the students who used deep processing in the game would have done so regardless of the game. Another situation where this relationship is interesting is when trying to achieve deep processing in groups. The distribution of learning approaches among group members could affect the group's susceptibility to deep processing in many ways; determining which mechanisms are genuine or not is important when seeking to understand deep processing in learning games. The result of comparing predisposition to learning approaches to deep processing scores achieved during gameplay (see Chapter 27) reveals no significant correlations; whereas this was expected for some relationships, it is unexpected for others.

Since the deep processing score does not take into account who in a group made the contributions that lead to the score a group gets, it is possible that only one or two students who are used to deep processing made all the relevant contributions, while other group members did, at least, not get in the way. If this was a common trend, one would expect the **maximum deep approach score** among members in a group to correlate with the deep processing score of the group. This correlation was, however, not observed in the results. As can be seen in Figure 27.3a, most groups are clustered centered around a maximum deep approach score of 3.75 and a deep processing score of 0.475. Two groups scored lower along both dimensions, which aligns with expectations, but they are too few to impact the correlation significantly. **The way the players were divided** does not lend itself well to finding this correlation; with group sizes of around five, selected randomly, a group is very likely to have at least one student with a high deep approach score, meaning that **the lower end of the spectrum has not been sampled sufficiently**. Having smaller groups or customizing groups based on players' deep approach scores can create contrast between groups to give more insight into this correlation. Another explanation for this correlation, if it turned out to be genuine, would be that this member's insight into the history subject and reasoning process could lead the whole group.

The strongest correlation observed was between the **minimum surface approach** score among group members and the deep processing score of that group, at -0.42. This comparison is visualized in Figure 27.4b. However, this correlation was still **weak and not statistically significant**, with a p-value of 0.176. Similar to the case with maximum deep approach score, the **sampling is here skewed** in the other direction; it is unlikely that a group of 5 random players does not have at least one player with a low surface approach score. Still, this correlation is somewhat present in the results. If this correlation is genuine, there exist at least **two different possible explanations**: (1) group members with a high surface approach score are directly responsible for the faulty contributions to the deep processing score, and (2) group members with a high surface approach score are indirectly responsible for a reduction in deep processing score – they limit group-wide emergent interactions through for example contributing negatively to motivation or pulling members out of *GameFlow*, the latter of which *Sweetser* and *Wyeth* warn about when creating games with social aspects [35].

28.3.4 Summary

Some characteristics of the deep processing that likely occurred during the experiments have been addressed. The results indicate that deep processing did take place during the experiments, even in the presence of effects that could lead the deep processing score to underestimate the actual deep processing that transpired. Circumstances relating to the operationalization of deep processing within games reveal that measurements *by condition* are comparatively easy to create, but the longevity of learning outcomes has not been tested. No correlations between learning approach scores and deep processing scores were particularly strong or statistically significant, but this might, in some cases, be attributed to experimentation design, especially surrounding group composition.

28.4 Research Question 4

How well does the developed lecture game incentivize deep processing for individuals and classes?

Collective Reasoning was developed to incentivize deep processing through gameplay. As mentioned in Section 28.1, the primary source of motivation for the players in the game is the competition through scores and a leaderboard, and as mentioned in Section 28.2, the game is designed to facilitate deep processing through the creation of an argument graph and the nature of *information gathering*. To answer research question 4, the correlation between the deep processing score and the game score is analyzed, and strengths and weaknesses regarding using ratings of elements in the graph to incentivize deep processing are discussed. There is also a discussion of the relation between different motivation sources in the game and the deep processing scores.

28.4.1 Score Correlation

Ideally, the game score would directly incentivize deep processing by awarding points for deep processing. After conducting the experiments, the deep processing score for each group was found by analyzing the relations created in the argument graph for signs of deep processing, as described in detail in Section 22.3. During gameplay, the game score is calculated by the game, based on the ratings from the evaluators, as detailed in Section 16.2. A correlation between the two sources would indicate that the game score represents deep processing, so the only way to do well in the game would be through achieving deep processing.

There seems to be a **correlation** between the deep processing score of an argument graph and the score it received in the game; however, it is not statistically significant. The correlation between the two scores in the experiments is 0.517, which is a moderate correlation. The p-value is 0.0705, meaning there is a 7.05% chance that a result would have occurred at least as extreme if there was no correlation between the deep processing score and the game score. This is not low enough to be statistically significant, but it is not very high either. With a larger sample size, the correlation could be statistically significant.

28.4.2 Game Score on a Micro, Meso, and Macro Level

The game score mainly evaluates the argument graph on a **micro level**. The rating on *inherent qualities* only looks at *facts* and *conclusions* in a vacuum, meaning the score is given without considering the argument graph as a whole. The *inherent qualities* include *clarity of presentation*, *relevance*, *trustworthiness of source*, *traceability*, and *plausibility.* All these qualities exist on a node level, and the score is given for each node. It is a strength of the gameplay that the evaluators only need to look at one node to give this score, as it makes it easier and faster to evaluate, meaning the players get quick feedback. Each reviewed node can give up to 350 points, or up to 700 points if the 2x-ability is used.

The *support* quality criterion of the game score is on a **meso level**, and it is unfortunate that this score is typically given toward the end of the game. The *support* quality criterion requires the evaluators to look at one *conclusion* or *answer conclusions* and all its supporting nodes, meaning the score is given for a node and its context. This is a strength for the gameplay, as it incentivizes the players to create argument graphs with a clear structure, where the *conclusions* are supported by *facts* and other *conclusions.* However, this criterion was given a rating after the players were finished. This was because the argument graph was not finished until the end of the game, and the evaluators needed to see the whole argument graph to give a rating. A rating given while playing could quickly be outdated, as the argument graph could change a lot during the game. The fact that the rating is given after the players can no longer edit their graph is a weakness of the gameplay. The players cannot improve the graph after receiving the rating, and cannot use the feedback to learn how to improve their argument graph. It is also a weakness because it does not motivate the students to make good relations, or relations at all, during the game, as they only get feedback on this at the end of the game. The support ratings can contribute around 1000 to 1500 points to the game score.

No part of the game score is given on a **macro level**, which is a weakness. No part of the score is given based on the entire graph, meaning the players are not incentivized to create an argument graph with a clear and well-thought-out structure. There is no score motivation for novelty and parsimony, which were mentioned as good qualities for an argument graph in Section 15.1. The players are not incentivized to create an argument graph with a clear and well-thought-out structure. Actually, the score incentivizes the opposite, as the players can get a higher score by creating more nodes and relations, even if the argument graph becomes more complex and harder to understand. Possibly, this is what Korint1, the group that added so many nodes and relations that the evaluators could not evaluate the graph, had understood. The definition of deep processing mentions developing an understanding of concepts, methods, and the connections between them and the ability to utilize this understanding in new situations [1]. The game score is meant to incentivize the players to utilize their understanding of new concepts in the game to create an argument graph that answers the session question, so evaluating the argument graph on a macro level should be a part of the game score.

28.4.3 Motivation Sources and Deep Processing

It seems like what motivation sources players were receptive to did not affect their deep processing score much. However, competition is the most promising motivation source for deep processing. Section 27.2 presented a table showing the distribution of motivation sources for each group, and the deep processing score for each group. The table showed that the groups with a high deep processing score were motivated by competition. The correlation coefficient was 0.418, and the p-value was 0.173, meaning it was not statistically significant. More samples would be needed to find a statistically significant correlation, but it is not unreasonable to assume there is likely a correlation between the two. The correlation could mean that competition is a good motivation source for deep processing. However, it could be the case that competition as a motivation source is not specifically well fit for deep processing, but just an effective motivation source in games in general. The correlation could also be a coincidence, as the sample size is small. The other motivation sources were less common in the game, and based on Table 27.1, it does not seem like they affected the deep processing score significantly.

28.4.4 Summary

The game tries to incentivize deep processing through gameplay, and it seems like the players were responsive to this to some degree, but the game score does not incentivize deep processing precisely. Ideally, the game score would directly incentivize deep processing by awarding points for deep processing. The correlation was 0.517, and the p-value was 0.0705, meaning it was not statistically significant. With more experiments and a larger sample size, finding a statistically significant correlation might be possible. The game score is not ideal for incentivizing deep processing, as it is based on reviews on a micro and meso level. The game score incentivizes the players to create more nodes and does not award parsimony. The players were responsive to competition, and the correlation between competition and deep processing was moderate, but not statistically significant. Otherwise, the motivation sources did not seem to affect the deep processing score significantly.

28.5 Validity of Results

The field of deep processing is struggling with consistency of operationalization and measurements of deep processing that are both generally applicable and valid [42]. The main measure for deep processing in this project is based on the conceptual model of the developed lecture game, specifically the components borrowed from argument graphs, components not likely to be found in other deep processing studies. The measure adheres to the definition of deep processing used in this project, but with one major discrepancy: It does not account for the longevity of the learning outcome of deep processing – an external validity concern. Definitions of deep processing vary between studies [42], so the results must be interpreted in light of the definition used in this project, the one by the *Norwegian Directorate for Education and Training* [1], further limiting the generalizability of the results of the measure. The deep processing measure is incompatible with a control group where the learning game is replaced with traditional learning, as the measure is based on concepts found in the game. The lack of a control group means it is harder to establish if it was the learning game that caused measurements, which is an internal validity concern. As explained in Section 23.1, deep processing observed during gameplay is almost certainly caused by the learning game, but without a baseline for traditional learning, the observed amount cannot be framed as good or bad.

The fact that only 53 of the 77 students (69%) who played the game in the experiments answered the questionnaire is an external validity concern. A low response rate is a common problem in research with questionnaires [9]. The questionnaire was given to the students in person, and they were asked to complete it during class to increase the response rate. Evidently, some still did not answer it. 56 is above 30 – the minimum sample size for small-scale research projects recommended by *Oates et al.* [9], but only for individuals. The sample size of groups will be discussed in the next paragraph. The body of students that did not answer the question might be correlated with those who did not like the game, did not experience deep processing, or any other measure of interest, making the body of students who answered the questionnaire unrepresentative of the wider population. Two other external validity concerns: All experiments were performed in history class, which might differ in compatibility with deep processing compared to other subjects, and all experiments were performed in Norway, whose educational system might prepare students more or less for deep processing compared to other regions of the world.

Generally, the sample size for groups is rather small, at only 14. This is the result of conflicting concerns. The project's short duration, especially the experimentation phase, limited the number of experiments that could be performed. In addition, because of the workload of evaluators during the gameplay scale with the number of groups, it was decided that the target group size should be five – relatively high. The small sample size meant that the statistical power of the correlation analysis was reduced and that the correlation coefficients observed might not represent the wider population; the aim for small-scale research projects should be to have at least 30 samples [9]. As discussed in Section 28.3.3, big groups lead to uniformity, meaning groups, their characteristics, and performance are harder to discern. From a research perspective, results could be more insightful and conclusive with smaller and more numerous groups, but with the usual size of classes being around 25, this is infeasible both during experiments and during a usual lecture setting, where only the teacher can act as an evaluator.

The results of this study must be viewed with the context and external validity concerns in mind, reducing the scope of where they are applicable. A small sample size of groups and the group selection process mean that fewer conclusions have been taken regarding correlations between deep processing and other phenomena.

28.6 Summary

This chapter discussed the results of the research in light of the research questions and the validity of the results. The results showed that the game *Collective Reasoning* did incentivize deep processing using different tactics and game elements, but there is room for improvement in the game. The results should be interpreted with the context and validity concerns in mind. The next chapter will conclude the discussion.

29 Conclusion

The goal of this project was to explore inducing *deep processing* through *learning games* by designing and developing the *lecture game Collective Reasoning* inspired by *deep processing*, and assess the game's ability to *motivate learning* and *facilitate deep processing*.

Using the game *Collective Reasoning* in experiments yielded findings about learning, enjoyment, and motivation **that align with established theories** (RQ1), which indicates that learning games concerning deep processing are fundamentally similar to other learning games. The implemented game design elements, such as social interaction and challenge, were enjoyable to the players. However, the lack of other elements from theories of enjoyment, such as fantasy and curiosity, limits the game's appeal to a wider range of players. Players derive limited benefit from a learning game they do not enjoy, as they will not be motivated to play it and thereby not be motivated to learn from it. The game design of a learning game concerning deep processing should therefore focus just as much on enjoyment as learning.

For learners to use deep processing on a subject, representations of concepts and relations from said subject must be at hand. For this to be the case in learning games with *flexible learning content*, an abstract representation that can accept arbitrary information must be an important aspect of gameplay, like *facts*, *conclusions*, and *support relations* are in our game. This severely limits what game concepts are even applicable to facilitate deep processing. Another aspect of the definition of deep processing that must be addressed is the utilization of information in new situations [1], but this places much fewer limitations on game design. This was solved in *Collective Reasoning* through the session question, unique to each session.

Several techniques were employed in our game to motivate and facilitate *deep processing*. The gameplay was based on constructing **argument graphs** [51], and **purposeful self-guided exploration** of the subject was an important activity in the game, both meant to facilitate deep processing (RQ2) – making it easier or natural to use. A **score mechanism** was used to align the challenge players face in the game with deep processing, partially through competition with other groups, thereby incentivizing players to use deep processing (RQ4). All **three** were implemented successfully, but not without revealing considerable design challenges. The conceptual model of *argument graphs* used in *lecture games* must be communicated clearly and thoroughly to tap into its potential, as should *score mechanisms*. In addition, care must be exercised when designing *score mechanisms*, so they align with and motivate desired behavior. The deep processing brought on by purposeful self-guided exploration of a subject is limited to those that actively participate; it is not enough to observe the results of the process – a limitation for player interaction design. These are not the only techniques used to facilitate and motivate deep processing in the game – another example is through collaboration – but the ones on which the data gave the most insight.

The results indicate that **deep processing occurred** during gameplay (RQ3), which demonstrates that games can be used to achieve deep processing. In the literature, deep and surface approaches to learning and deep processing are deeply connected conceptually. Against expectations, however, no particularly strong or statistically significant correlations were found between learning approach scores and deep processing scores. This may be attributed to certain aspects of the experiment design, especially regarding group composition and small sample size.

The occurrence of deep processing in our game *Collective Reasoning* is a promising finding for learning games concerning deep processing. Traditional learning game design theories and techniques are still applicable, but facilitating deep processing in games introduces unique game design limitations.

30 | Master's Thesis Retrospective

This chapter will examine the project's overall process, highlighting its successes and identifying areas with potential improvement. We chose an ambitious project by wanting to explore the idea of deep processing in learning games. This combination is not a well-researched area. Conducting a preliminary study, developing a game, conducting experiments, analyzing the results, and writing a thesis is a lot of work, and we had to make some compromises to finish the project in time. We will discuss choices and compromises made in the following sections.

30.1 Preliminary Study

A large portion of the preliminary study was based on a literature review. We used the preliminary study from the specialization project [2] as a starting point for the preliminary study in the master's thesis. There was some overlapping relevant literature, so this was expedient and saved us some time. The specialization project had a more general scope on lecture games, and we had to update and extend the preliminary study to fit the scope of deep processing in learning games. Not much research is yet conducted on deep processing in learning games, so we had to combine research areas, specifically deep processing and game-based learning, to find relevant information. From our perspective, the literature review reasonably represents the relevant research areas, and we found some interesting research that helped us design the game.

We also conducted interviews with teachers as part of the preliminary study in the specialization project, and the findings were very insightful for the master's project. Since we are students in the field of computer technology and have minimal teaching experience, hearing what the teachers had to say was very valuable. The interviews gave us a better understanding of what teachers want from a learning game, and the challenges they face when using games in the classroom. Some teachers mentioned the new learning curriculum in Norwegian schools, which inspired us to focus on deep processing. The teachers also gave us valuable insight into the context of the game, which helped us design a game that fits into the classroom. Conducting interviews was a good choice, and we would likely have missed some important aspects of the game if we had not done so.

30.2 Game Design and Development Methodology

We had ambitious ideas for *Collective Reasoning* when we started the project. The original game idea described in the specialization project [2] placed the game in a fantasy setting, where the players would be philosophers developing argument graphs in a fantasy world. The evaluators would be Greek gods in this fantasy, and the players would receive ratings through curses and blessings. This was a fun idea, but in hindsight, it is clear it was impossible for two developers within the timeframe of this research project. The time allocated for game development was about three months. We could not have spent more time developing the game and still had time to test it and analyze results, but it was not a reasonable time frame to develop the concept we originally wanted to develop. We had to make some compromises to finish the game in time, and we decided to simplify the game by removing the fantasy setting. The only remnants of the fantasy setting are the name of the groups, which are Greek cities. We might have been able to implement the game if we had started with a more realistic fantasy scope. With a fantasy setting, the game would have been more in line with *Malone*'s enjoyment theory [34], and the game would likely be more fun to play and thereby better suited for research on games, specifically deep processing in games.

The collaboration between the two developers was good, and we used a suitable development methodology for the project. We understood each other's strengths and weaknesses well and divided the work in a way that suited us both. We had a good workflow for developing the game, and we worked independently on different parts of the game. Using *Git* for version control worked okay, even though it is not ideal for Unity meta files. We used *GitHub* for hosting the repository, which worked well for collaboration, as we also used *GitHub* project board as a kanban board to keep track of tasks and progress. We worked agile by having regular meetings and discussing the project's progress, which ensured progress and adaptability throughout the development. The developed game worked seamlessly in all three experiments, which is a testament to the quality of the game development.

30.3 Experiments and Results

More could have been done to get more responses to the questionnaire, which would have yielded more valid results. 69% of the players answered the questionnaire. This is a decent response rate, but more responses would have been better. Most students started answering the questionnaire, but some did not finish it. The questionnaire was quite lengthy, but they should have been able to finish it in the allocated 15 minutes, as the average time to complete the questionnaire was about 10 minutes. We could have shortened the questionnaire, but we wanted to include all our planned questions. We should have emphasized more how vital their answers are for our experiments. We could also have asked the students to be silent while answering as some students seemed to distract each other and lost focus on the questionnaire. We respect the students choosing not to answer the questionnaire since it is voluntary, and they are not obligated to answer, but we would have liked to have more responses to get more valid results.

30.4 Summary

All in all, we are happy with the project. We have learned a lot about game-based learning, deep processing, and lecture games. A general trend in the project is that we have had to make compromises to finish the project on time. Some effort was expended designing and preparing the game implementation for the planned fantasy elements. Not pursuing a significant fantasy component might have freed up more time for other priorities, such as experiment planning. However, we are happy with the game we developed, and we are proud of the results our research has achieved. We achieved our goal of exploring the idea of deep processing in learning games, and the results are promising.

31 | Further Work

To conclude this project, we suggest some further work to continue the work of this project and directions to take the concept of deep processing in learning games forward.

The causal link between enjoyment and learning in learning games is a fundamental hypothesis within the field of game-based learning. It is regrettable then that our game, *Collective Reasoning*, scored an average of only 3.09, a subpar score for a game. Improving the game's enjoyment could lead to a higher learning outcome and a greater measurable impact of employing the game. The aspect of fantasy – when a game evokes social situations or realities not actually present – is important for enjoyment in games [34]. In our game, *Collective Reasoning*, fantasy can be implemented by analogizing constructing argument graphs with the work of philosophers in ancient Greece, and the role of evaluators can be likened to the judgment of the Olympian gods. As is visible from the names given to the groups, the possibility of implementing this fantasy was considered during the development of the game *Collective Reasoning*. Some other concepts from the era that could represent game mechanics and artifacts in the game *Collective Reasoning* are cities, buildings, technology, and social structures. The game can also be improved in other ways, like small audible and visual feedback on actions throughout the game, a tutorial, in-game explanations for game concepts and mechanisms, and a unique visual profile.

The research took place in Norway and exclusively in the history subject in upper secondary education (aged 17-18). Scandinavia is seemingly well-represented in research into deep processing and argument graphs [46, 47, 50, 51]. It is interesting to see if studies on deep processing in learning games in other regions, with different education systems and cultures, would align with the conclusions in this study. The same goes for other subjects, like language, social sciences, biology, and even math, and testing the game with different age groups.

Studying the learning in the game *Collective Reasoning* over time is an interesting direction for further work – both (1) addressing the **longevity** of the learning outcome and (2) whether the characteristics of the learning outcome change on **subsequent utilization** of the learning game. This study does not directly test the **longevity** of learning outcomes, relying on the self-report questionnaire and the students' intuition to gauge this value. The learning outcome on **subsequent utilization** of *Collective Reasoning* can improve because the players will know the game's mechanisms and goals, or it can deteriorate because the game loses its novelty. Longer studies that interact with each class over a period of time can address both of these aspects.

Further research into deep processing in learning games could include using another game concept, which would help find which results of this study are generalizable and which are more specific to our game *Collective Reasoning*. New game concepts that facilitate deep processing must, as discussed in Section 28.2.3, make concepts and relations from the learning content available inside the game. This is conceivable to do in, for example, quiz-like games as the representation are quite abstract and flexible; maybe this genre is a place to start.

Using artificial intelligence (AI) to evaluate argument graphs can solve many problems that were discovered related to argument graphs in learning games. The evaluation workload for teachers would be reduced, and it would create opportunity and flexibility for implementing score mechanics that target all levels of desired behavior – micro, meso, and macro – either by having AI evaluate all three levels or freeing up the teacher to evaluate only the levels least fit for AI evaluation. Reducing the evaluation workload is also necessary to employ the game in practice instead of just being a subject of research. It would also enable dividing the class into smaller and more numerous groups, which would also mitigate further three problems: (1) it will be easier for group members to maintain a complete picture of their own argument graph; (2) groups with fewer members are likely to diverge further from the average, giving more conclusive results; (3) more groups will lead to higher sample sizes and higher statistical power.

Bibliography

1. Norwegian Directorate for Education and Training. *Dybdelæring* https://www.udir.no/laring-og-trivsel/dybdelaring/ (2022).
2. Leithe, J. & Schøyen, L. N. Collaborative Classroom Learning Games (TDT4501 Specialization Project). *Norwegian University of Science and Technology* (2022).
3. Clayton, K., Blumberg, F. & Auld, D. P. The relationship between motivation, learning strategies and choice of environment whether traditional or including an online component. *British Journal of Educational Technology* **41,** 349–364 (2010).
4. Wang, C. & Huang, L. A Systematic Review of Serious Games for Collaborative Learning: Theoretical Framework, Game Mechanic and Efficiency Assessment. *International Journal of Emerging Technologies in Learning* **16** (2021).
5. Medietilsynet. Gaming og pengebruk i dataspill. *BARN OG MEDIER 2020* (2020).
6. Subhash, S. & Cudney, E. A. Gamified learning in higher education: A systematic review of the literature. *Computers in human behavior* **87,** 192–206 (2018).
7. Laal, M. & Ghodsi, S. M. Benefits of collaborative learning. *Procedia-social and behavioral sciences* **31,** 486–490 (2012).
8. Caldiera, V. R. B. G. & Rombach, H. D. The goal question metric approach. *Encyclopedia of software engineering,* 528–532 (1994).
9. Oates, B. J., Griffiths, M. & McLean, R. *Researching Information Systems and Computing* (Sage, 2022).
10. Prensky, M. Digital game-based learning. *Computers in Entertainment (CIE)* **1,** 21–21 (2003).
11. Al-Azawi, R., Al-Faliti, F. & Al-Blushi, M. Educational gamification vs. game based learning: Comparative study. *International journal of innovation, management and technology* **7,** 132–136 (2016).
12. Plass, J. L., Homer, B. D. & Kinzer, C. K. Foundations of game-based learning. *Educational psychologist* **50,** 258–283 (2015).
13. Sanchez, E., van Oostendorp, H., Fijnheer, J. D. & Lavoué, E. in *Encyclopedia of Education and Information Technologies* 816–827 (Springer, 2020).
14. Tekinbas, K. S. & Zimmerman, E. *Rules of play: Game design fundamentals* (MIT press, 2003).
15. Qian, M. & Clark, K. R. Game-based Learning and 21st century skills: A review of recent research. *Computers in human behavior* **63,** 50–58 (2016).
16. Karakoç, B., Eryılmaz, K., Turan Özpolat, E. & Yıldırım, İ. The effect of game-based learning on student achievement: A meta-analysis study. *Technology, Knowledge and Learning,* 1–16 (2022).
17. Westera, W. Games are motivating, aren't they? Disputing the arguments for digital game-based learning. *International Journal of Serious Games* **2,** 3–17 (2015).
18. Camilleri, M. A. & Camilleri, A. C. *The students' perceptions of digital game-based learning* in *European Conference on Games Based Learning* (2017), 56–62.
19. Warren, S. J., Jones, G., Warren, S. J. & Jones, G. What Is (and Is Not) a Learning Game? *Learning Games: The Science and Art of Development,* 15–26 (2017).

20. Wu, B. Theoretical Foundation for Lecture Games (2013).
21. Wang, A. I. & Tahir, R. The effect of using Kahoot! for learning–A literature review. *Computers & Education* **149,** 103818 (2020).
22. Wang, A. I. & Lieberoth, A. *The effect of points and audio on concentration, engagement, enjoyment, learning, motivation, and classroom dynamics using Kahoot* in *European conference on games based learning* **20** (2016).
23. Benson, R. M. *Games based learning* PhD thesis (University of Warwick, 2014).
24. Deterding, S., Dixon, D., Khaled, R. & Nacke, L. *From game design elements to gamefulness: defining" gamification"* in *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments* (2011), 9–15.
25. Dicheva, D., Dichev, C., Agre, G. & Angelova, G. Gamification in education: A systematic mapping study. *Journal of educational technology & society* **18,** 75–88 (2015).
26. Shortt, M., Tilak, S., Kuznetcova, I., Martens, B. & Akinkuolie, B. Gamification in mobile-assisted language learning: A systematic review of Duolingo literature from public release of 2012 to early 2020. *Computer Assisted Language Learning* **36,** 517–554 (2023).
27. Huynh, D., Zuo, L. & Iida, H. *Analyzing gamification of "Duolingo" with focus on its course structure* in *Games and Learning Alliance: 5th International Conference, GALA 2016, Utrecht, The Netherlands, December 5–7, 2016, Proceedings 5* (2016), 268–277.
28. Zagal, J. P., Rick, J. & Hsi, I. Collaborative games: Lessons learned from board games. *Simulation & gaming* **37,** 24–40 (2006).
29. Manninen, T. Interaction forms and communicative actions in multiplayer games. *Game studies* **3** (2003).
30. Johnson, S. *Analysis: Turn-based versus real-time* Nov. 2009. https://www.gamedeveloper.com/pc/analysis-turn-based-versus-real-time.
31. Harris, J., Hancock, M. & Scott, S. D. *Leveraging asymmetries in multiplayer games: Investigating design elements of interdependent play* in *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play* (2016), 350–361.
32. Norwegian Directorate for Education and Training. *Tverrfaglige temaer* https://www.udir.no/lk20/overordnet-del/prinsipper-for-laring-utvikling-og-danning/tverrfaglige-temaer/ (2022).
33. Norwegian Directorate for Education and Training. *Core curriculum – values and principles for primary and secondary education* https://www.udir.no/lk20/overordnet-del/?lang=eng (2022).
34. Malone, T. W. *What makes things fun to learn? Heuristics for designing instructional computer games* in *Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems* (1980), 162–169.
35. Sweetser, P. & Wyeth, P. GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment (CIE)* **3,** 3–3 (2005).
36. Csikszentmihalyi, M. *Flow: The psychology of optimal experience* (Harper & Row New York, 1990).
37. Wang, H. & Sun, C.-T. *Game reward systems: Gaming experiences and social meanings.* in *DiGRA conference* **114** (2011).
38. Gee, J. P. Learning by design: Good video games as learning machines. *E-learning and Digital Media* **2,** 5–16 (2005).
39. Tahir, R. & Wang, A. I. *Codifying game-based learning: The league framework for evaluation* in *Proceedings of the 12th European Conference on Game Based Learning (ECGBL 2018), Sophia Antipolis, France* (2018), 4–5.
40. Nagowah, L. & Nagowah, S. A Reflection on the Dominant Learning Theories: Behaviourism, Cognitivism and Constructivism. *International Journal of Learning* **16** (2009).
41. Amineh, R. J. & Asl, H. D. Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages* **1,** 9–16 (2015).

42. Dinsmore, D. L. & Alexander, P. A. A critical discussion of deep and surface processing: What it means, how it is measured, the role of context, and model specification. *Educational psychology review* **24,** 499–567 (2012).

43. Smith, T. W. & Colby, S. A. Teaching for deep learning. *The clearing house: A journal of educational strategies, issues and ideas* **80,** 205–210 (2007).

44. Biggs, J. B. *Student Approaches to Learning and Studying. Research Monograph.* (ERIC, 1987).

45. Howie, P. & Bagnall, R. A critique of the deep and surface approaches to learning model. *Teaching in Higher Education* **18,** 389–400 (2013).

46. Marton, F. & Säljö, R. On qualitative differences in learning: I—Outcome and process. *British journal of educational psychology* **46,** 4–11 (1976).

47. Marton, F. & Säaljö, R. On qualitative differences in learning—ii Outcome as a function of the learner's conception of the task. *british Journal of educational Psychology* **46,** 115–127 (1976).

48. Entwistle, N., Hanley, M. & Hounsell, D. Identifying distinctive approaches to studying. *Higher education* **8,** 365–380 (1979).

49. Biggs, J. & Tang, C. *Teaching for Quality Learning at University* (McGraw-hill education (UK), 2011).

50. Kiili, C. Online reading as an individual and social practice. *Jyväskylä studies in education, psychology and social research* (2012).

51. Kiili, C. Argument graph as a tool for promoting collaborative online reading. *Journal of Computer Assisted Learning* **29,** 248–259 (2013).

52. Gordon, T. F. & Walton, D. *The Carneades argumentation framework–using presumptions and exceptions to model critical questions* in *6th computational models of natural argument workshop (CMNA), European conference on artificial intelligence (ECAI), Italy* **6** (2006), 5–13.

53. Murphy, D. *Learning Approach Questionnaire - items and scale structure* University of Melbourne (2020). https://melbourne.figshare.com/articles/online_resource/Learning_Approach_Questionnaire_Dan_Murphy_docx/12101433.

54. Biggs, J., Kember, D. & Leung, D. Y. The revised two-factor study process questionnaire: R-SPQ-2F. *British journal of educational psychology* **71,** 133–149 (2001).

55. Schollmeier, R. *A definition of peer-to-peer networking for the classification of peer-to-peer architectures and applications* in *Proceedings First International Conference on Peer-to-Peer Computing* (2001), 101–102.

56. Bhardwaj, R., Dixit, V. & Upadhyay, A. K. An overview on tools for peer to peer network simulation. *International Journal of Computer Applications* **1,** 74–81 (2010).

57. Rahimi, N. Security consideration in peer-to-peer networks with a case study application. *International Journal of Network Security & Its Applications (IJNSA) Vol* **12** (2020).

58. Amrit, T. *Platform Ecosystems. Aligning Architecture, Governance, and Strategy* (Morgan Kaufmann, Elsevier, Waltham, MA, 2014).

59. Pinto, C. M. & Coutinho, C. *From Native to Cross-platform Hybrid Development* in *2018 International Conference on Intelligent Systems (IS)* (2018), 669–676.

60. IONOS, D. G. *Runtime environments: Explanation and examples* Dec. 2020. https://www.ionos.com/digitalguide/websites/web-development/what-is-a-runtime-environment/.

61. aws. *What's The Difference Between Web Apps, Native Apps, And Hybrid Apps?* 2023. https://aws.amazon.com/compare/the-difference-between-web-apps-native-apps-and-hybrid-apps/ (2023).

62. Miller, R. *The tectonics of the web* June 2018. https://frontendian.co/the-tectonics-of-the-web.

63. Xie, J. *Research on key technologies base Unity3D game engine* in *2012 7th international conference on computer science & education (ICCSE)* (2012), 695–699.

64. Electronic Arts. *The Sims 4 system requirements* https://help.ea.com/en-gb/help/the-sims/the-sims-4/the-sims-4-system-requirements/#pc (2023).

65. Patt, T. *spam urbanism* 2010. https://www.flickr.com/photos/trevorpatt/4473540126/ (2023).

66. Norwegian Directorate for Education and Training. *Competence aims after vg3 programmes for general studies* https://www.udir.no/lk20/nor01-06/kompetansemaal-og-vurdering/kv115?lang=eng (2022).

67. Brush, K. & Silverthorne, V. *Agile software development* Nov. 2022. https://www.techtarget.com/searchsoftwarequality/definition/agile-software-development.

68. Beck, K. *et al. Manifesto for Agile Software Development* 2001. http://www.agilemanifesto.org/.

69. Rehkopf, M. *What is a Kanban Board?* https://www.atlassian.com/agile/kanban/boards (2023).

70. Rehkopf, M. *User stories with examples and a template* https://www.atlassian.com/agile/project-management/user-stories (2023).

71. Bass, L., Clements, P. & Kazman, R. *Software Architecture in Practice* Third Edition (Addison-Wesley, 2012).

72. Prasanna, D. *Dependency injection: design patterns using spring and guice* (Simon and Schuster, 2009).

73. Norwegian Directorate for Education and Training. *History (HIS01-03) Competence aims and assessment* https://www.udir.no/lk20/overordnet-del/?lang=eng (2022).

74. Mukaka, M. M. A guide to appropriate use of correlation coefficient in medical research. *Malawi medical journal* **24,** 69–71 (2012).

75. Ernst, M. D. Permutation methods: a basis for exact inference. *Statistical Science,* 676–685 (2004).

76. Phipson, B. & Smyth, G. K. Permutation P-values should never be zero: calculating exact P-values when permutations are randomly drawn. *Statistical applications in genetics and molecular biology* **9** (2010).

77. Perera, A. Hawthorne Effect: Definition, How It Works, and How to Avoid It (2021).

78. Instanes, J. T. *The pros and cons of collecting data through self-report questionnaires* Feb. 2021. https://newbrainnutrition.com/the-pros-and-cons-of-collecting-data-through-self-report-questionnaires/.

79. ILETC. *Learning Approach Questionnaire* Apr. 2020. http://www.iletc.com.au/wp-content/uploads/2020/05/T-0013.pdf.

A | Raw Interview Findings

A list of tables with findings from the interviews follows. The findings are expressed in English. The identities of teachers and schools have been obfuscated.

Findings that can be found in multiple, or aggregated from the findings of multiple, interviews		
ID	**Finding**	**Source**
G3	Consensus or understanding of a definition of learning games seems to not be established for teachers. Is it a game that's used made for the school context or a game where the players learn?	H3, M3, V3, T3
G4	Some teachers make use of physical games, such as board games and card games.	E3, K3, K5, V4, V6, T9
G5	Kahoot! is widely used in the interviewed middle and secondary schools.	H4, A4, K6, M4
G6	Performance in Kahoot! is not a good representation of student performance.	K7, M51
G7	Quizlet, and especially the feature Quizlet Live, is widely used in the interviewed middle and secondary schools.	A4, M4, T5
G8	Students are motivated by games.	H10, T46
G9	Students enjoy digital quiz games.	H10, T46
G10	Coding is now part of the math and natural sciences in the new national curriculum of Norway.	H5, A25, E26, V39
G11	Math teachers are still quite ill-fit to teach programming.	H34, E35
G12	Teachers believe that learning games have a big future potential to be a motivating learning activity.	H6, M9, V8, T44, T45
G13	The new national curriculum of Norway focuses on discussions and reasoning.	H13, V24
G14	Teachers believe group works in games works as well or better than traditional group works.	H14, A11, E11, V18
G15	Many of the students, especially the boys, are motivated by competition.	H18, A6, V5, T6
G16	Learning games that challenge the students to think and reflect during the game will give the most learning outcome.	H19, V56
G17	Students need to be familiar with a game [goals, controls, etc.] to learn efficiently.	A13, K21, M29, V22, T20
G18	Teachers must know the learning games they make use of. [The game itself and how it can be used in teaching.]	H20, A14, implied by E15, M27
G19	Finance related circumstances can get in the way of learning game deployment.	H21, M19
G20	If the learning outcome of a learning game is apparent, the teachers will be motivated to learn how to use it.	E16, T23
G21	At the schools of teachers interviewed, internet access and WiFi coverage are now generally good, and it has been improving.	H24, A24, K26, V46, T33
G22	Teachers in STEM subjects sometimes utilize interactive simulations for teaching purposes.	H28, A3
G23	A game often appears less threatening than other methods or representations of tasks.	H32, E12, T16
G24	Both learning games with static and flexible learning content have a space in education.	H37, A32, E32, K36, M43, M44, M45, T40, T41

G25	Games can also be used to great effect as a change of pace, breaks, or rewards for finishing other work.	H38, A9, E6, E21, T12
G26	It is required that a variety of teaching activities is used for good a learning outcome.	H39, K28, T18
G27	Escape-room style progression system may be suitable for a quiz-like learning game.	A8, E33
G28	Students are increasingly using electronic devices during school activities, including most writing, and otherwise.	H7, E23, M38, T29

Findings from the interview with Teacher H		
ID	**Finding**	**Source**
H3	Teacher H does not believe she has used learning games. [She is then referring to digital learning games. It appears she does not consider Quiz games to be learning games.]	Interview
H4	Teacher H used Kahoot a lot previously, but less so now due to limited options when you don't have a premium subscription.	Interview
H5	Coding is a part of the maths subject at secondary school, as it is required by the new curriculum. Teacher H teaches block programming.	Interview
H6	Teacher H believes that the potential of learning games in education is great.	Interview
H7	Aneta finds that the students are generally interested in computers, and want to use computers as much as possible, which supports the statement in H6.	Interview
H8	Teachers need to control that the students do what they are supposed to when they are using computers.	Interview
H9	Students are more digital than manual, they prefer writing on the computer over writing by hand.	Interview
H10	Students enjoy digital quizzes.	Interview
H11	Many students enjoy learning to code.	Interview
H12	Typical for group work at school is that a few students do most of the work, while the rest do little.	Interview
H13	The new curriculum focuses on discussions and reasoning, which can be done in group work, but it is a challenge that only a few students participate in the discussion.	Interview
H14	Teacher H does not believe group work in learning games will differ much from group work in general, considering participation in group work.	Interview
H15	Teacher H finds that the students who are usually best at school are not always the same as the students who are best at programming.	Interview
H16	Students who struggle in school sometimes find it more interesting to learn in untraditional ways, for example by using the computer.	Interview
H17	Teacher H has not used learning games enough to give a confident answer as to how the effectiveness of learning games changes based on how much they are used.	Interview
H18	Many of the students, especially the boys, are motivated by competition.	Interview
H19	Teacher H believes that learning games that challenge the students to think and reflect during the game will give the most learning outcome. She does not want a game that allows the students to just choose among multiple-choice alternatives without reflecting on the answers.	Interview
H20	Teachers will typically need an introduction course explaining how to use a game or resource before they will use it in class	Interview
H21	Teachers typically do not get funding to attend courses that require payment.	Interview
H22	All the students have school-issued Chromebooks.	Interview
H23	Middle School U does not want the students to use their mobile phones in class, some exceptions are ok in smaller groups.	Interview

H24	The internet connection at Middle School U is generally good. Some challenges are experienced if all students use it at the same time.	Interview
H25	The batteries in the Chromebooks are typically not very good; some Chromebooks must be charged every day.	Interview
H26	Teacher H teaches math, natural sciences, and an elective, called ideas and practical research.	Interview
H27	The new curriculum in nature science does not include previously challenging parts of the curriculum, such as carbon chemistry, alcohols, acids, genetics, optics, etc.	Interview
H28	Teacher H uses digital simulations from the University of Colorado, where the user can build circuits, show molecules, etc.	Interview
H29	It is typical that some students do not understand maths, and Teacher H experiences that no matter what the teacher does, they still do not understand maths.	Interview
H30	A learning game may be suitable for visualization of algebra used in everyday situations.	Interview
H31	Teacher H sometimes uses Campus Inkrement and Matematikk.org as digital resources in maths. Here students solve tasks, usually manually on paper, and then input their answers.	Interview
H32	Algebra and equations may feel less foreign and scary for students if it is presented as a part of a game.	Interview
H33	At Matematikk.org the students get diplomas for finishing tasks, such as multiplication tables. Diplomas may be a bit childish, but they can also be popular among students.	Interview
H34	Programming in math is in Python, which few teachers are familiar with. Teacher H, therefore, feels like someone who has education within the field of computers should be the one to teach the students programming.	Interview
H35	It is currently challenging for 10th graders to learn to code, as they have not been taught any coding in the 8th and 9th grades.	Interview
H36	Students struggle to understand Geogebra and CAS.	Interview
H37	Both learning games with specific learning content and flexible learning content is useful but may be fit for use in different contexts and curriculum.	Interview
H38	Quiz Games, such as Kahoot are suitable for more than learning, and may also be used just for fun.	Interview
H39	The students like variation.	Interview

Findings from the interview with Teacher A		
ID	**Finding**	**Source**
A3	Teacher A has utilized interactive animations when teaching. For physics: students can change parameters (speed, friction, etc.) to see how it affects a motion.	Interview
A4	Teacher A has utilized quiz-like learning games, such as Quizlet, Kahoot, and Mentimeter	Interview
A5	Games and animations can visualize a problem in a helpful way for students to learn.	Interview
A6	A competition element triggers many students' motivation.	Interview
A7	A good learning game may be a virtual world with a competition where the students must know the subject to progress in the game.	Interview
A8	A possible game idea is Escape rooms with questions from for example math, history, and geography.	Interview
A9	Games can be used to create variation.	Interview
A10	Learning games may not be suited for all groups of students.	Interview
A11	Students struggling socially and struggling with group work might find it easier to collaborate in a game than in normal classroom settings.	Interview
A12	Using a learning game "too much" (such as Kahoot in all subjects) may make it less interesting to the students.	Interview
A13	Students getting familiar with a game will increase the learning outcome.	Interview
A14	Teachers must know what the intended learning outcome is for a game to be able to choose the right game for the right class and time.	Interview
A15	At Secondary School B students use either private computers or iPads at school.	Interview
A16	Students may use cell phones in class.	
A17	In physics classes, loggers are used to gather data, such as temperature, speed, and distance.	Interview
A18	Software such as GeoGebra is accessible on both iPads and computers, so all students have access to it.	Interview
A19	Computers or tablets are best suited for learning games, phones may be too small. It depends on the game, Quizlet and Kahoot are well suited to play on phones.	Interview
A20	The county provides software to students and teachers that may be used in school (Programvaresenteret).	Interview
A21	Teacher A is not aware of any given regulation when it comes to required operative system accessibility for software used by the teacher or students.	Interview
A22	The teacher must be sure that a website is safe before asking students to use it or download anything from it.	Interview
A23	The publishing houses have good animation and digital aids. Teachers and students have licenses to access these resources.	Interview
A24	Students do not usually experience slow network access or network connection issues at Secondary School B. This was a more regular problem previously. There was once some trouble with digging over a cable.	Interview
A25	Coding is taught in physics and mathematics.	Interview
A26	The number of power sockets is a problem in some classrooms at Secondary School B. They have socket towers to help with this situation.	Interview

A27	Teacher A teaches Physics 2, Math R2, and math for "Yrkesfag". She can also teach Technology and Research (TOF) and natural sciences.	Interview
A28	Quantum physics is struggling to teach to students because it is hard to understand.	Interview
A29	Abstract phenomena and concepts are harder to teach to students.	Interview
A30	Learning games may be used to show things at a different scale than you can experience/show in a classroom setting-. Examples: objects moving at 99% of the speed of light, large distances, very small objects (quantum physics), the inside of the body, the digestive system	Interview
A31	Teacher A thinks that games with animations should have specific learning content. This type of game will be easier to start using if it is inherently linked to specific competence aims in the curriculum.	Interview
A32	Both games with flexible learning content and specific learning content can be useful in all subjects.	Interview
A33	Complex games are easier to start using in schools if teachers have less options to adjust.	Interview
A34	Many students play games as a hobby, so using learning games will be a new addition to the classroom.	Interview

Findings from the interview with Teacher E		
ID	**Finding**	**Source**
E3	Teacher E utilizes learning games when teaching. Mostly board games and card games, some of which were self-made, for example in math classes.	Interview
E4	When asked, students state they want to use learning games during classes.	Interview
E5	The desire referenced in finding E4 does not itself lead to a higher learning outcome in activities utilizing learning games. A deeper understanding has not resulted from these activities.	Interview
E6	Games can give motivation. The students got the opportunity to play the jumping frog puzzle [it is unclear what game this is] and solitaire when done with their tasks, instead of getting just more tasks. With this, they were motivated to get through their tasks quickly.	Interview
E7	Teacher E feels that games utilized should have some connection to the subject being taught and that there is learning outcome from playing the game.	Interview
E8	The rules of the games should not be too complex, as the students might give up.	Interview
E9	It's good to have games where the students must collaborate, but at the same time, it's good to have games where the students must work alone. It could vary.	Interview
E10	The teaching is often adapted to the weak students, not the strong students. Learning games with collaborative elements can be used to provide learning and challenge for a group of strong students [if the level of challenge is flexible enough].	Interview
E11	It might be easier to get all group members engaged in a group activity using learning games because it is harder to lay back.	Interview
E12	A game appears less threatening than a paper sheet with tasks, so students are willing to give learning games a try.	Interview
E13	The learning outcome might be enhanced by following up learning game activities with a discussion on the learning outcome of the game, connections, and tying it to the subject.	Interview
E14	For some games, it is a big challenge that the teacher does not know the game, for example Minecraft.	Interview
E15	It's important that the teacher does not have a hard time getting to know the game and how it can be used.	Interview
E16	If the learning outcome of a learning game is apparent, the teachers will be motivated to learn how to use it.	Interview
E17	Middle School D issues iPads to each student.	Interview
E18	Teacher E and co require that students meet to school with iPads already charged.	Interview
E19	In general, the iPad fleet arrangement causes some frustration. Teacher E just arrived from a class where one iPad did not work at all.	Interview
E20	Only math class uses handwriting; in other subjects, students usually write on their iPads.	Interview
E21	Teacher E thinks that games utilized must generate motivation [for learning the subject at hand] and work as a change of pace [/variation].	Interview

E22	Teacher E thinks computers are the best devices for learnings games. [Without stating a reason.] She also says this is valid for other activities, like working with spreadsheets and exams.	Interview
E23	Teacher E thinks students use screens so much already that additional usage do not change their perception of electronic devices in the school context.	Interview
E24	Teacher E states that students get less distracted in games than other activities.	Interview
E25	Teacher E teaches math and the culture heritage elective, and is involved in special education.	Interview
E26	Teacher E is unsure and eager to see how the teaching of programming in math is going to go, if the students will develop the understanding or not. Using the Python programing language, only very simple programs can be achieved in practice at their level. For example printing stuff to the screen. Block programming, through for example Scratch, is more promising in this regard.	Interview
E27	During classes of the programming elective, the students use computers, not iPads.	Interview
E28	Math anxiety is a problem. Students who do not like math are not receptive to traditional teaching methods in the math subject.	Interview
E29	Learning games can help the problem outlined in finding E28.	Interview
E30	Teacher E is more positive to learning games with flexible learning content, than specific learning content.	Interview
E31	Teacher E finds it intuitive that it's difficult to combine serious games with learning content.	Interview
E32	Contrasting finding E30, Eva thinks specific learning content learning games might be more applicable in the cultural heritage elective than the math subject.	Interview
E33	Teacher E wants a math game with tasks in a number of chapters, and with an escape room-esque progression system.	Interview
E34	Learning games with specific learning content that don't cover a lot of the curriculum must be very easy to employ, otherwise, the time invested is not worth the learning outcome, and are in general harder to employ.	Interview
E35	Even with 15 ECTS of programming subjects at tertiary education level, Teacher E is not completely confident she can teach programming well.	Interview
E36	Teacher E wants a learning game that can be used at any time. [Most likely flexible learning outcome, and with the students already knowing the game.]	Interview
E37	In math [at least], the teaching style has moved away from repetitive exposure to topics, to more consolidated learning of topics timewise. Students are done with statistics in middle school in 9th grade, which is not repeated in 10th grade. It's going to be interesting to see how the students fare during the exam with topics they learned back in 8th grade, 2 years ago.	Interview

Findings from the interview with Teacher K		
ID	**Finding**	**Source**
K3	Teacher K has utilized board games in language classes.	Interview
K4	Teacher K has sent the students links to online grammar games.	Interview
K5	Teacher K has utilized war-themed (1st and 2nd world war) board games to teach students about war strategies and development.	Interview
K6	Teacher K does not use Kahoot for the entire class, as the same students are usually in the top each time, which is not motivation for the other students. Using Kahoots in smaller groups give all the students an opportunity to shine.	Interview
K7	In Kahoot the motivation to answer quickly means the students take more chances, and reflect less about what they answer.	Interview
K8	Kahoot does not work well for students struggling with reading and/or writing, as they are not as quick as the other students.	Interview
K9	New Amigos (board game) works well in the class, because all students experience achieving something in the game, which is motivating.	Interview
K10	The important aspects of whether Teacher K would use a learning game is the learning outcome and the sense of accomplishment the students experience.	Interview
K11	Teacher K would like a game that could be used for a big part of the curriculum, and that is so flexible that it can be adapted to different themes.	Interview
K12	Being able to use a learning game in Teacher Eluation/assessment context would be splendid.	Interview
K13	Collaboration elements in learning game is beneficial to the psychosocial learning environment, since no student is left alone.	Interview
K14	Kahoot! and competitions in general can be a nightmare in a class full of very competitive students. Collaboration could work better in these classes.	Interview
K15	Students who are mostly silent may find it easier to communicate in games than in normal classroom settings, especially if they do not need to communicate with the entire class.	Interview
K16	Some students are quite interested in war.	Interview
K17	The students have surprisingly little patience, so being able to vary the teaching is important.	Interview
K18	Due to K17, students may prefer learning games with variations, or using multiple different learning games.	Interview
K19	Learning games may be beneficial to spark interest among students who are not that interested in learning in general.	Interview
K20	The students are playful, so a element of play is important.	Interview
K21	Teacher K believes students will have increased learning outcome from a game after using it a couple of times, however this also depends on the complexity of the game.	Interview
K22	Students at Middle School U uses Chromebook.	Interview
K23	All the students in 9th and 10th grade has their own Chromebooks, in 8th grade there are less computers, so more planning is necessary to use the computer.	Interview

K24	The students spend a lot of time using computers and mobile phones, there are therefore also benefits to not using such devices constantly, to give them a break.	Interview
K25	The type of game affects what device is best suited for a learning game.	Interview
K26	The WiFi at Middle School U works well.	Interview
K27	Using smart boards in the classrooms at Middle School U is challenging due to technical problems, for example problems with the speakers or the projector.	Interview
K28	Variation makes the teaching interesting for the students.	Interview
K29	Teacher K teaches English, English specialization and social studies. She has previously taught Religion and Production for the stage.	Interview
K30	Students find it scary to talk in English in class, it is a challenge to gather enough basis for the teacher to grade the students on oral english.	Interview
K31	Teacher K asks the students deliver audio files to hear them speak English.	Interview
K32	History and historical developments are well suited topics for learning games.	Interview
K33	English pronunciation are well suited for learning games.	Interview
K34	Teacher K dreams of a game where the students speaking are saved as audio files that the teacher can examine later.	Interview
K35	Many students spontaneously speak english while gaming at home.	Interview
K36	Learning games with both specific and flexible learning outcome can be useful.	Interview
K37	Teachers are constantly looking for new ways to vary their teaching to excite the students.	Interview

Findings from the interview with Teacher M		
ID	**Finding**	**Source**
M3	Teacher M was unsure what a learning game was. Is it a game that's made for the school context or a game where players can learn?	Interview
M4	Middle School D has employed the games Geoguessr, Minecraft, Kahoot!, Quizlet, and Quizlet Live for teaching purposes.	Interview
M5	Learning games are used less in 10th grade, because a lot of content needs to be learned in a short amount of time.	Interview
M6	Learning games might be relTeacher Ent for an oral exam. [It is unclear how or why.]	Interview
M7	Some learning games, like those used in math, can be used without much time investment.	Interview
M8	The implementation of [most] games in education, like Minecraft or Civilisation, needs weeks.	Interview
M9	The potential of learning games might be big, but it must be used correctly.	Interview
M10	When Teacher M utilized Minecraft in 8th grade, the students were very engaged – they wanted to perform the task and put in effort – but not much learning remained after, for example, building something.	Interview
M11	The teachers at Middle School D have tried using Minecraft in many different ways: Sustainable city, look around, but it was not effective.	Interview
M12	Teacher M has tried to persuade Middle School D to acquire gaming hardware.	Interview
M13	Middle School D does not possess gaming hardware.	Implied by M12
M14	Gaming hardware would allow, e.g. is required, for demanding games, like Democracy, Civilization, to be used in education.	Interview
M15	Democracy can show the intricacy of politics – how difficult it all is to balance. The students still think pouring money solves any problem. Would be good to use in social sciences.	Interview
M16	Civilization teaches the importance of resources and diplomatics. Needs to keep neighbors happy; learns about international relations. The resources you have access to basically determine the power you have.	Interview
M17	A game can only be used if it is supported on the electronic devices available.	Interview
M18	The iPads used at the Middle School D suffer from a lack of persistent storage.	Interview
M19	The apps to be used on the iPads at the Middle School D can't contain ads, therefore, there are few free apps that can be used.	Interview
M20	In practice, financial resources is needed to acquire learning game apps.	Interview, M19
M21	More free apps without ads are available on computers than tablets.	Interview
M22	The utilization of learning games by Teacher M is hampered by lack of funding and equipment.	Interview, M13, M20
M23	Students are to cooperate [most likely in groups] when building in Minecraft.	Interview
M24	Teacher M and co observes that students who are good at cooperating to begin with manage cooperation well, while those who are not might end up disagreeing, starting to build separately, suddenly making use of explosives, sabotaging for each other.	Interview

M25	Teacher M thinks it is unrealistic that the school can make one gaming computer available for each student.	Interview
M26	When playing games like Civilization, students will have to share computers and cooperate; there would probably be problems, but it is an opportunity to learn cooperation.	Interview, M25
M27	Teachers must know the games they make use of. In some cases, this knowledge comes from self study or hobbies, fueled by individual interests.	Interview
M28	Teacher M, as the only teacher, or one of few, that plays Minecraft, is the one that knows how to use it and the main driver for its use in education at Middle School D. Teacher M thinks this is a shame, since it probably works better in other subjects than her own, for example in math, to teach coordinate systems.	Interview
M29	There is a initial period when the students need to learn how to play the game itself, instead of the intended learning content. The second or third class, when students were building in Minecraft [– from 45 to 90 minutes in and afterwards], they knew more about how it works.	Interview
M30	Depending on the game, some students might have played it before while others haven't.	Interview
M31	Teacher M states that her students don't really seem to get tired of games in education. Individuals sometimes play a learning game from math classes without needing. Some of them play Minecraft in their free time; maybe not so much anymore, in tenth grade.	Interview
M32	Middle School D issues iPads and associated external keyboards to each student, and each classroom has a SMART Board.	Interview
M33	Teacher M thinks a early 2000-esque situation with computer labs and some stronger machines would work better for learning games.	Interview
M34	Teacher M's school-issued work laptop can barely run Minecraft.	Interview
M35	Teacher M and co require that students meet to school with iPads already charged.	Interview
M36	It varies if students are able to comply with the policy in M35. If the students know they'll play Minecraft, they are more likely to have charged their iPads.	Interview
M37	Students bring mentally what they did before into the next class; if they were building in Minecraft in social science, they'll want to continue doing that into math class, or they might play the math game in other classes. Of course, a game is more fun than listening to a lecture on the industrial revolution. This is a negative consequence.	Interview
M38	The iPads are heavily used in all subjects at Middle School D, maybe with the exception of math class. Although students have the option of writing on paper, they don't often use this opportunity.	Interview
M39	Teacher M teaches KRLE [e.g. religion and ethics], social sciences, and English.	Interview
M40	Teacher M recalls that students have a hard time with KRLE [e.g. religion and ethics] as a subject.	Interview
M41	Minecraft was utilized to attempt to tackle the problem referred to in M40. This is the reason she has used Minecraft most in KRLE [e.g. religion and ethics]. Marte found an example of a temple, which all students were supposed to build. Now, they think all temples look like that one temple.	Interview

M42	English is easy to teach with the help of learning games. It can be used as a setting, or situation, in which students can practice English. Teacher M, for example, got her students to create Minecraft tutorials and guides in English.	Implied in interview
M43	Teacher M wants a combination of both games with specific learning content and flexible learning content.	Interview
M44	The initial time needed to teach students how to play a game might not be worth it if it's only used a couple classes and never again, which might be the case for games with specific learning content. Games with flexible learning content, on the other hand, can be used on multiple occasions.	Interview
M45	Games with specific learning content might be easier to employ because they do not usually require that much customization or preparation. Examples of such work can be: Creating an appropriate Minecraft world, or meticulously crafting groups to minimize the chance of sabotage and trolling.	Interview
M46	Math classes might need learning games that are more clear about what they are trying to teach.	Interview
M47	It was during the COVID-19 pandemic that Minecraft became a topic of interest at the school.	Interview
M48	Teacher M is disappointed by the learning outcome achieved in Minecraft activities in education so far.	Interview
M49	It is a problem that the students get too focused on the game and too little on the learning. This problem might be alleviated by utilizing learning games that are not usually played at home. The students might have an easier time separating between playing at home and playing to learn at school.	Interview
M50	Kahoot! is used in all subjects. It is often used for repetition in subjects, or as a break or play activity with quizzes only tangentially relTeacher Ent for subjects.	Interview
M51	Kahoot! is not a good representation of how well a student knows a subject, as they can cheat and look over each others shoulders, but it facilitates a good vibe.	Interview
M52	It's not necessarily the students which perform well at school that score the highest in Kahoot! quizzes not related to school, so this can be an opportunity for other students to shine. For example, a student was very good at flags because he played a lot of FIFA.	Interview
M53	Teacher M wants a game where objects, artifacts, historical texts, historical individuals, beliefs, etc. is to be sorted into the world religions. Optimally with time-pressure, or time score, like in Quizlet.	Interview
M54	Sometimes, in Quizlet Live, one student takes over all screens, but most of the time it works well.	Interview

Findings from the interview with Teacher V		
ID	**Finding**	**Source**
V3	Teacher V has utilized digital learning resources from sources such as Norwegian Digital Learning Arena, but no software that's developed specifically for the lecture environment; there we'll use more boardgames – self-made or bought.	Interview
V4	Teacher V has utilized **¡New Amigos!** and **lotto** in German class.	Interview
V5	The competitive spirit of students can be harnessed for learning purposes.	Interview
V6	The physical pieces and situation creates a specific goal that can guide students.	Interview
V7	A technique Teacher V sometimes uses in combination with learning board games is the implementation of a progress system, where students need to finish the task in one room to be able to progress to the next room.	Interview
V8	Many students are interested in gaming and games. There is a potential to use learning games to reach these students.	Interview
V9	Games could exist that allows for exploration of different eras in the history of literature or history, with tasks and artifacts like contemporary works, which must be solved or processed before one can progress. Such games could definitely be interesting.	Interview
V10	Virtual reality can be used instead of physical travel for simulating travelling to relTeacher Ent locations for culture studies in the language subjects.	Interview
V11	Teacher V does not know if she has many gamers in her class, because they have just started on Secondary School S.	Interview
V12	Teacher V's niece attends middle school, they game a lot. [It is unclear if it refers to the household of the niece or the school.]	Interview
V13	Students are very good at English, since they use it on their phone and while gaming.	Interview
V14	Teacher V wishes it would be as cool to use German as English.	Interview
V15	The learning outcome of students is paramount for the decision of whether to use learning games.	Interview
V16	It would be valuable if a learning game is able to motivate students to learn intrinsically, or learn without being aware of it, even when not at school.	Interview
V17	Duolingo is used by a Spanish teacher at the school, and they are able to see that some students practice Spanish glossary, for example in the middle of the summer holiday. This is an example of a game generating motivation, instead of directly learning outcome.	Interview
V18	Teacher V thinks that psychosocial circumstances are so intricate and complex that cooperation problems that do arise, arise no matter what kind of cooperation the student is to take part of, either it is in games or in traditional group works.	Interview
V19	Some students escape into virtual worlds to escape the social aspects of physical interaction. Interaction online can be limited, e.g. with no web camera. In addition, it's is often goal oriented. All of this makes it easier for students who struggle socially to engage in interaction through games.	Interview
V20	Learning games has the potential of connecting students or individuals in other countries and schools, as well as being used in one classroom.	Interview

V21	Teacher V predicts that the language used in international interaction through learning games is going to be English no matter what one tries, but wishes that such interaction would be in other languages, like German.	Interview
V22	It takes time before students gets into the goals and learns the tools. This is true for other situations too, like the transition from middle school math to secondary school math. Learning games must also be used for quite some time to be effective.	Interview
V23	Teachers must be willing to try out new techniques if learning games is to be adapted.	Interview
V24	The new curriculum [in the Norwegian education system] puts a lot of emphasis on exploration, investigation, and curiosity. The curriculum is in general shorter. It takes more time to ponder over issues than to just go through the content that should be learned.	Interview
V25	Learnings games fits very well in regards to finding V24.	Interview
V26	The most important electronic device at Secondary School S is the personal computer.	Interview
V27	The students that enroll at Secondary School S do not know how to use a computer anymore, so this has to be taught here. The same level of computer literacy, for example text editing skills, is taught and tested during 11th grade as was previously taught and tested during 8th grade. They do know how to use phones and tablets. Lite [mobile] versions of games, of course, do exist, but for applications where typing is required, it is better to use computers. Computer literacy is generally falling.	Interview
V28	The health courses has bought VR headsets, to maybe be able to practice digitally. These might also be used to simulate travel in language subjects in the future.	Interview
V29	Windows, OS X and ChromeOS can all be found among the personal computers of students.	Interview
V30	Windows is the required operating system for personal computer in the secondary education system in the county. OS X and Chromebook users sometimes have a hard time handing in assignments and other tasks because their devices are incompatible.	Interview
V31	Students with OS X computers also do not know how to use them. For example, saving and finding files are difficult tasks.	Interview
V32	Computer literacy, and recognition of computers as tools, is so important [for secondary education right now] that it would be valuable that learning games can be combined with exploration of computers.	Interview
V33	Phones are being used regularly for learning games, for example for Kahoot!.	Interview
V34	Students still like Kahoot!, even though it is quite old.	Interview
V35	The school this teacher works at utilizes mobile phone hotels, so it is the teacher that determines when phones are available to the students and not.	Interview
V36	Students are equally easily distracted by the internet on their computers as on phones, except for Snapchat notifications.	Interview
V37	OS X is to a higher and higher degree also compatible with the IT systems of the county.	Interview
V38	Linux is all but non-existent among personal computers of students. This might be related to finding V27.	Interview

V39	Programming is being introduced into the curriculum.	Interview
V40	Finding V39 will possibly and hopefully counteract finding V27.	Interview
V41	Teacher V wishes that students already coming from middle school knew Windows to such a degree that teachers at secondary education level could teach other operating systems, like Linux, especially for STEM students.	Interview
V42	Distribution of applications is most seamless through Windows installers.	Interview
V43	Teacher V wishes that the technology stack of the county was based on Linux instead of Windows. The lack of technical support is often the limiting factor being referred to in the discussion, but the lack of technical support comes from a lack of talent, which can be explained by the lack of Linux in education.	Interview
V44	Incompatibilities with operating systems and applications are solved on a case-by-case basis.	Implied by interview
V45	New software developed for and introduced in the secondary education system in the county should be compatible with Microsoft.	Interview, V30
V46	WiFi coverage quality varies from room to room at Secondary School S.	Interview
V47	Power sockets is usually not a problem. They have socket towers to help with this situation.	Interview
V48	Each classroom has Android smart boards now. [It is unclear if these are SMART Boards or Smart boards by other brands.] All apps available on the Google Play Store are available on these smart boards.	Interview
V49	In general, students are easily distracted. Even a hare running by can take the wind out of the sail of a lecture.	Interview
V50	Teacher V thinks computers probably are not to detrimental in this regard, in fact if learning games were very immersive and at the same time educational, it can even counteract the problem.	Interview
V51	Teacher V teaches Norwegian and German.	Interview
V52	The parts of curricula that are harder to teach varies depending on the class.	Interview
V53	Reproduction of speech and written text without the use of tools is a difficult skill for students to learn.	Interview
V54	Teacher V thinks learning games are fit teach grammar in foreign languages.	Interview
V55	Teacher V is interested in the development of learning games with multidisciplinary learning content through historical eras. For example: Cooperation with tasks from physics or chemistry, as well as tasks related to politics, all set in the 1600s. The history of Germany can also be used.	Interview
V56	The new curriculum has focus on **deep approach to learning** – which, among other things, means to build connections between the subjects – and introduces three multidisciplinary topics to be taught in all subjects when applicable: Sustainable development (1), democracy and citizenship (2), health and life skills (3).	Interview
V57	Learning games with learning content overlapping with the multidisciplinary topics in finding V56 has the opportunity to cover lager parts of the overall cirriculum than subject-focused games. A lesser focus on the subjects in the branding of the game could help students realize the connections between subjects.	Interview

V58	The game Tove most wants developed is described by findings V55, V56, and V57.	Interview

Findings from the interview with Teacher T		
ID	**Finding**	**Source**
T3	Teacher T was unsure what a learning game was.	Interview
T4	Teacher T teaches Norwegian, Spanish and music subjects.	Interview
T5	In Spanish classes, Teacher T employs some learning games. For example, **Quizlet**, specifically **Quizlet Live**, is used to teach beginner level. Another game where students draw words from a pool and has to use the word in a sentence or conjugating it.	Interview
T6	Quizlet Live, especially the competitive element, is captures the attention of the students a lot.	Interview
T7	Teacher T has given the task of creating learning games to 10th grade students [, board and card games,] with supplied topic and difficulty. Teacher T keeps the games and uses them with other students.	Interview
T8	Teacher T employs less games in Norwegian classes.	Interview
T9	Teacher T has used the board game **Alias** [, similar to Taboo,] to teach word definitions and synonyms.	Interview
T10	Teacher T has used the game **What am I?** to teach about people and terms in both Norwegian and Spanish classes.	Interview
T11	Games can be used to make students learn subconscious, especially with competitive elements, like in NRK's Klassequizen and Quizlet Live.	Interview
T12	Games can be used as a change of pace, breaks or variation.	Interview
T13	It's important for Teacher T that learning games capture the attention and focus of students.	Interview
T14	It's important for Teacher T that the students of all levels experiences learning outcome from learning games.	Interview
T15	It's important for Teacher T that learning games are easy to employ. Students often understands games before the teacher. How easy a learning game is to employ is not always limited by the student side of the comprehension. The preparation time for teachers also affect this. **Kahoot!** and **Quizlet** have pre-made quiz sets that can shorten this time, but are definitely acceptable in this regard.	Interview
T16	Games should appear harmless – there shouldn't be a big pressure to perform. There are insecure students.	Interview
T17	Teacher T implies that it's negative that the it is readily presented who performs well and who doesn't, especially the latter element. The bigger the group is, the worse this gets. It's okay to be worse out of 4 students once in a while, but not out of 30.	Interview
T18	In general, variation in school activities is important; this does not change with learning games.	Interview
T19	If Quizlet Live is used in every class, students can get tired of it, but Teacher T is not sure if the learning outcome is affected. The game might be viewed as just another activity, instead of something anticipated.	Interview
T20	On the other hand, a game should be employed enough times for the students to learn the game, which will increase learning outcome.	Interview
T21	Using a learning game over time, and not excessively, can be important.	Interview
T22	Teacher T thinks that herself and teachers in general are receptive to new techniques and ideas for teaching.	Interview

T23	Teachers will put effort into learning how to use something new if it is shown to be effective.	Interview
T24	Teacher T is not very skilled in playing **Minecraft**; another teacher from the same school is better. This might lead to her using the game less in teaching.	Interview
T25	Students are generally skilled at playing **Minecraft**.	Interview
T26	Teacher T gives tasks like building well known buildings or making portraits of famous people in Minecraft.	Interview, T25
T27	Another teacher found a **Minecraft** world made for learning Nynorsk. [In this context, Minecraft was used as a platform with learning applications.]	Interview
T28	All students have their own iPad [issued by the school] and an external associated keyboard.	Interview
T29	The students use iPad for producing text in all subjects. Teacher T adds that she thinks this is unfortunate. [It is unclear if she thinks it's unfortunate only in Norwegian classes or in general.]	Interview
T30	Teacher T shares that many of the external iPad keyboard do not work, so they'll have to use the screen keyboards to write many pages.	Interview
T31	Teacher T thinks the type of device that is optimal varies from learning game to learning game. Phones and tablets work well for quiz games, but with bigger games and movement of an avatar, tablets are the bare minimum, but computers are even better for this.	Interview
T32	There aren't enough power sockets at Middle School D, but this isn't much of a problem because the students aren't allowed to charge at school anyway. In practice however, many students don't remember to charge their iPads at home every day.	Interview
T33	The internet [maybe also WiFi] has improved over time, and there's rarely problems at Middle School D anymore. The internett access is sometimes down, but rarely compromised.	Interview
T34	Students do not get official graded feedback every semester anymore, but rather only a grade in the Norwegian subject in 10th grade.	Interview
T35	Nynorsk, the secondary Norwegian written language in this region, is difficult to teach compared to the rest of the Norwegian subject. This is exacerbated by finding T34 because the attitudes changes [It's not specified towards what] and the effort the teachers put down are in line with this reduced feedback.	Interview
T36	Some students have the preconception that Nynorsk is something they don't like before they start at the lower secondary education level.	Interview
T37	In music, less and less work is being put into [teaching or learning] sheet music. It is a difficult topic to teach and it's not specifically mentioned in the curriculum, which only mentions learning music notation in general.	Interview
T38	In Spanish class, grammar is difficult, but what the students need more is vocabulary.	Interview
T39	Teacher T thinks repetitive and technical tasks and topics are best for learning games, but she realizes that she might be biased by exposure to traditional games.	Interview

T40	Teacher T sees the uses of both specific and flexible learning content learning games. Learning games with specific learning content might be easier to employ in the classroom, but it's unrealistic that all parts of the curriculum can be covered by such games. Some areas must therefore be covered by flexible learning content learning games, if anything.	Interview
T41	Teacher T thinks that schematic topics, such as sheet music, grammar and certain topics in math might work better for specific learning content learning games.	Interview
T42	Teacher T thinks that questions within ethics and morals will probably have to be adjusted based on setting.	Interview
T43	Teacher T wants a game that motivates students to learn Nynorsk and improves students attitude towards it.	Interview
T44	Teacher T thinks learning games is going to be important and thinks it's nice that someone is working on it.	Interview
T45	Teacher T thinks games and learning games work for all ages.	Interview
T46	Quizlet and Quizlet Live has not lost its charm to 10th grade students even though they've used it a lot for a long time. There are options for variability: Cooperation or alone, etc.	Interview
T47	Teacher T thinks 10th grade students who game a lot in their free time might find Minecraft dull. It depends on the task, is it motivating and captures their attention.	Interview

B | Evaluation Guide

The *evaluation guide* for how to evaluate the quality of *facts* and *conclusions* in *Collective Reasoning* follows. The guide is in Norwegian.

C | Player Learning Approaches

The following table shows the *learning approach* scores of the participants in the *experiments*. The scores are calculated as the average of the scores of the *learning approach* questions in the *questionnaire*.

Table C.1: Measured learning approach scores of participants.

Participant ID	Deep approach score	Surface approach score
kin-hip-jih	3.125	3.5
kew-yeg-buc	3.0	2.75
hur-vif-lug	1.625	2.5
cin-dij-cad	2.25	4.125
nof-wun-wom	2.625	3.125
nut-xeb-xoz	3.125	4.375
dal-vem-dom	1.875	3.375
ber-wef-bad	2.375	3.25
hat-kid-vad	2.5	3.125
nog-leb-wuh	2.75	3.0
yic-wix-guf	4.125	2.0
jec-tiw-ner	2.875	2.625
vik-kap-cuj	2.75	3.5
zer-fos-mah	3.125	2.75
cir-des-lev	2.375	3.5
hod-run-yud	2.5	4.0
dev-diw-gon	3.0	3.5
baf-vap-cay	2.625	2.875
mux-geb-job	2.5	3.25
soy-rez-rol	2.75	3.0
can-men-gov	3.0	3.5
yos-haw-liw	2.375	3.875
fow-nah-mux	4.125	5.0
poy-bur-duf	2.375	4.125
til-xiw-zol	1.875	4.375
jic-viv-gab	2.875	2.75

Continued on next page

Table C.1: Measured learning approach scores of participants. (Continued)

Participant ID	Deep approach score	Surface approach score
boz-juj-sut	3.75	2.375
wew-wok-wuy	2.875	3.5
zof-sar-hed	3.625	2.375
tex-sic-rot	3.0	3.5
mux-cer-dat	3.0	2.0
xok-cuh-bay	3.375	2.875
tel-pak-bap	2.875	3.25
yof-sal-caj	3.625	2.5
vib-lur-cuh	3.0	3.125
hur-fem-rud	2.75	3.125
vus-ler-cox	3.625	2.75
xel-tuc-hip	2.75	2.375
yef-hak-fel	3.625	3.125
fat-nay-pas	3.375	4.0
sit-yur-vij	3.625	3.625
xas-pig-vek	2.25	2.375
wub-yex-fix	3.875	3.25
lut-hux-rol	2.75	3.25
xap-ban-kem	2.75	3.75
lex-hix-boz	2.625	2.75
mup-lec-rin	3.375	3.375
faz-vuz-buk	1.375	2.125
duv-gim-wan	3.875	3.5
luy-vum-nej	3.0	2.375
tav-pow-bop	3.25	3.75
bos-goy-zaw	2.75	4.25
ref-piv-kab	2.75	3.125

D | Information Participants Read Before Consenting

The information document that participants read before consenting to participate in the study follows.

Vil du delta i forskningsprosjektet *Collaborative Classroom Learning Games*?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke virkningen av samarbeidsspill til læring i klasserommet. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Prosjektet er en masteroppgave ved NTNU i Trondheim, Fakultet for informasjonsteknologi og elektroteknikk, Institutt for datateknologi og informatikk. Formålet med prosjektet er å gjennomføre et eksperiment hvor vi undersøker virkningen samarbeidsspill kan ha på læring, motivasjon og engasjement i et klasserom. Under eksperimentet skal deltagere spille et flerspillerdataspill vi har utviklet samt besvare spørsmål via spørreundersøkelse slik at vi kan analysere faktorene nevnt over.

Hvem er ansvarlig for forskningsprosjektet?

Professor Alf Inge Wang ved Institutt for datateknologi og informatikk ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Du blir spurt siden du går på en videregående skole vi har kontaktet angående eksperimentet.

Hva innebærer det for deg å delta?

Ved å delta i dette prosjektet er du med i et eksperiment der du bruker spillet vårt, Collective Reasoning, i en økt. Du vil få en introduksjon til spillet, og etter økten vil du få svare på et spørreskjema.

Data vil bli samlet inn gjennom spørreskjemaet og lagring av handlinger i spillet. Spørreskjemaet handler om tidligere spillerfaring, holdninger til skole, noen personlig opplysninger – navn, epost-adresse, kjønn og alder – samt effekten spilløkten har på hatt læring, engasjement og motivasjon. Spillet vil loggføre dine handlinger i spillet. Denne informasjonen lagres og kan knyttes til deg.

Data blir lagret elektronisk. Data vil bare potensielt bli gjort tilgjengelig for læreren eller skolen i en anonymisert tilstand. All data som kan bli brukt til å identifisere deg vil bli slettet ved prosjektets slutt, eller tidligere dersom du ber om det.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet.

Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. De som ikke ønsker å delta vil få et alternativt opplegg i timen(e) det gjelder, og deltagelse vil ikke ha noen innvirkning på forholdet mellom skolen/lærer og deg, hverken i eller utenfor faget.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Det er kun oss – forfatterne av masteroppgaven – og vår veileder som vil ha tilgang til personopplysningene innhentet i eksperimentet. Navn og kontaktinformasjon vil lagres i en separat liste fra resten av dataen. Du får utdelt en identifikasjonskode som skal fylles inn i spørreskjema og i spillet. Identifikasjonskoden blir brukt for å knytte personopplysninger med assosiert data. Personopplysningene lagres sikkert i NTNU sine tjenester i henhold med universitetets rammeverk for lagring av sensitiv data (https://i.ntnu.no/wiki/-/wiki/English/Data+storage+guide).

I den ferdigstilte masteroppgaven kan følgende persondata bli publisert: Kjønn, alder, tidligere spillerfaring og faginteresse. Dette vil i så fall ikke bli knyttet til individuelle deltagere, og vil derfor ikke kunne brukes til å identifisere deltakere.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 12.06.2023. Navn og kontaktinformasjon vil da slettes, og all annen data vil anonymiseres.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.
På oppdrag fra Institutt for datateknologi og informatikk ved NTNU har Sikt vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Forfatterne av masteroppgaven:
    - Jorunn Leithe – jorul@stud.ntnu.no
    - Leonard Nguyen Schøyen – leonarns@stud.ntnu.no
- Veileder:
    - Alf Inge Wang – alf.inge.wang@ntnu.no
- Vårt personvernombud:
    - Thomas Helgesen – thomas.helgesen@ntnu.no

Hvis du har spørsmål knyttet til Personverntjenester sin vurdering av prosjektet, kan du ta kontakt med:

- Personverntjenester på e-post (personverntjenester@sikt.no) eller på telefon: 53 21 15 00.

Med vennlig hilsen

Alf Inge Wang	Jorunn Leithe	Leonard Nguyen Schøyen
(Forsker/veileder)	(Forfatter)	(Forfatter)

E | Sikt Application

The notification form for personal data for the research in this project, which was approved by Sikt, follows.

Sikt

Meldeskjema / Masteroppgave - Collaborative Classroom Learning Games / Eksport

Meldeskjema

Referansenummer
233533

Hvilke personopplysninger skal du behandle?

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Bakgrunnsopplysninger som vil kunne identifisere en person
- Andre opplysninger som vil kunne identifisere en fysisk person

Beskriv hvilke bakgrunnsopplysninger du skal behandle

Alder, kjønn, skole

Beskriv hvilke andre opplysninger som vil kunne identifisere en person du skal behandle

hobbyer, interesser

Prosjektinformasjon

Prosjekttittel

Masteroppgave - Collaborative Classroom Learning Games

Prosjektbeskrivelse

Prosjektet er en masteroppgave ved NTNU i Trondheim, Fakultet for informasjonsteknologi og elektroteknikk, Institutt for datateknologi og informatikk.

Formålet med eksperimentet er å undersøke hvordan bruk av samarbeidsspill påvirker elevers læring. Under eksperimentet vil elever ta i bruk et webbasert dataspill vi har utviklet. Før og etter eksperimentet vil vi gjennomføre en spørreundersøkelse for å analysere hvilken effekt spillet har hatt på elevene.

Begrunn hvorfor det er nødvendig å behandle personopplysningene

Navn brukes når testdeltagerne skriver under på samtykkeskjema/informasjonsskriv. Vi trenger epost for å distribuere spill og spørreskjema. Bakgrunnsinformasjon (kjønn, alder, skole og hobbyer/interesser) benyttes for å analysere applikasjonens effekt i forskjellige deltagerkategorier.

Ekstern finansiering
Ikke utfyllt
Type prosjekt
Studentprosjekt, masterstudium

Kontaktinformasjon, student
Jorunn Leithe, jorul@stud.ntnu.no, tlf: 9498535

Behandlingsansvar

Behandlingsansvarlig institusjon
Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Alf Inge Wang, alf.inge.wang@ntnu.no, tlf: 73594485

Skal behandlingsansvaret deles med andre institusjoner (felles behandlingsansvarlige)?

Nei

Utvalg 1

Beskriv utvalget

Skoleelever

Beskriv hvordan rekruttering eller trekking av utvalget skjer

Via elevenes skole og lærer

Alder
15 - 19

Personopplysninger for utvalg 1
- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Bakgrunnsopplysninger som vil kunne identifisere en person
- Andre opplysninger som vil kunne identifisere en fysisk person

Hvordan samler du inn data fra utvalg 1?

Elektronisk spørreskjema

Vedlegg

Spørreundersøkelse Collaborative Classroom Learning Game.pdf

Grunnlag for å behandle alminnelige kategorier av personopplysninger
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Hvem samtykker for barn under 16 år?
Foreldre/foresatte

Hvem samtykker for ungdom 16 og 17 år?
Ungdom

Ikke-deltakende observasjon

Grunnlag for å behandle alminnelige kategorier av personopplysninger
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Hvem samtykker for barn under 16 år?
Foreldre/foresatte

Hvem samtykker for ungdom 16 og 17 år?
Ungdom

Informasjon for utvalg 1

Informerer du utvalget om behandlingen av personopplysningene?
Ja

Hvordan?
Skriftlig informasjon (papir eller elektronisk)

Informasjonsskriv

Informasjonsskriv CCLG.pdf

Tredjepersoner

Skal du behandle personopplysninger om tredjepersoner?
Nei

Dokumentasjon

Hvordan dokumenteres samtykkene?

- Manuelt (papir)

Hvordan kan samtykket trekkes tilbake?

Samtykke kan trekkes tilbake ved å kontakte forfatterene i prosjektet. Deltagerene blir opplyst om dette i informasjonsskriv som inneholder kontaktopplysninger.

Hvordan kan de registrerte få innsyn, rettet eller slettet personopplysninger om seg selv?

Deltagerene kan kontakte forfatterene i prosjektet. Deltagerene blir opplyst om dette i informasjonsskriv som inneholder kontaktopplysninger.

Totalt antall registrerte i prosjektet
1-99

Tillatelser

Skal du innhente følgende godkjenninger eller tillatelser for prosjektet?
Ikke utfyllt

Behandling

Hvor behandles personopplysningene?

- Maskinvare tilhørende behandlingsansvarlig institusjon
- Ekstern tjeneste eller nettverk (databehandler)

Hvem behandler/har tilgang til personopplysningene?

- Student (studentprosjekt)
- Prosjektansvarlig
- Databehandler

Hvilken databehandler har tilgang til personopplysningene?

Office 365 (kjører innenfor NTNUs SharePoint)

Tilgjengeliggjøres personopplysningene utenfor EU/EØS til en tredjestat eller internasjonal organisasjon?
Nei

Sikkerhet

Oppbevares personopplysningene atskilt fra øvrige data (koblingsnøkkel)?
Ja

Hvilke tekniske og fysiske tiltak sikrer personopplysningene?

- Flerfaktorautentisering
- Opplysningene krypteres under forsendelse
- Adgangsbegrensning
- Endringslogg

Varighet

Prosjektperiode
01.03.2023 - 12.06.2023

Hva skjer med dataene ved prosjektslutt?
Data anonymiseres (sletter/omskriver personopplysningene)

Hvilke anonymiseringstiltak vil bli foretatt?

- Koblingsnøkkelen slettes
- Personidentifiserbare opplysninger fjernes, omskrives eller grovkategoriseres

Vil de registrerte kunne identifiseres (direkte eller indirekte) i oppgave/avhandling/øvrige publikasjoner fra prosjektet?

Nei

Tilleggsopplysninger

F Player Groups

Table F.1: Participants in each player group.

Experiment ID	Group name	Participants
1	Aten	dal-vem-dom
		kew-yeg-buc
		nog-leb-wuh
		sar-vov-poz
		tex-ded-sov
		vik-kap-cuj
1	Egina	dev-diw-gon
		fem-ded-gev
		hur-vif-lug
		yic-wix-guf
		zer-fos-mah
1	Korint	baw-yex-huw
		dux-pob-wuy
		fuw-sam-jax
		heb-moc-men
		vuf-nev-nos
1	Rodos	ber-wef-bad
		jec-tiw-ner
		kin-hip-jih
		nil-gum-fix
		nut-xeb-xoz
1	Sparta	cin-dij-cad
		cir-des-lev
		hat-kid-vad
		hod-run-yud
		nof-wun-wom

Continued on next page

Table F.1: Participants in each player group. (Continued)

Experiment ID	Group name	Participants
2	Aten	boz-juj-sut
		can-men-gov
		hur-fem-rud
		soy-rez-rol
		til-xiw-zol
		yos-haw-liw
2	Egina	baf-vap-cay
		goy-mec-geb
		vib-lur-cuh
		xel-tuc-hip
		yof-sal-caj
2	Korint	fow-nah-mux
		tel-pak-bap
		tex-sic-rot
		wew-wok-wuy
		zof-sar-hed
2	Rodos	fat-nay-pas
		haw-but-nuf
		mux-cer-dat
		sit-yur-vij
		yef-hak-fel
2	Sparta	jic-viv-gab
		mux-geb-job
		poy-bur-duf
		vus-ler-cox
		xok-cuh-bay
3	Aten	lex-hix-boz
		luy-vum-nej
		mup-lec-rin
		nuy-nuj-doj
		wan-ruy-pol
		xas-pig-vek
3	Egina	bew-ves-pem
		cey-gig-tiy
		tox-vup-teh
		xap-ban-kem
		xos-huy-bum

Continued on next page

Table F.1: Participants in each player group. (Continued)

Experiment ID	**Group name**	**Participants**
3	Rodos	bos-goy-zaw
		bul-zar-noh
		lut-hux-rol
		ref-piv-kab
		wub-yex-fix
3	Sparta	duv-gim-wan
		faz-vuz-buk
		hiz-mic-gol
		mog-roc-dim
		nuf-baw-bur
		tav-pow-bop

G | Questionnaire

The questionnaire that participants filled out after the experiment follows.

Spørreundersøkelse Collective Reasoning

Kun anonymisert data fra denne undersøkelsen kan deles med læreren eller skolen.
Det vil si at læreren IKKE får vite hva du har svart.

* Obligatorisk

Grunnleggende Informasjon

1. Hva heter du (fornavn og etternavn)? *

2. Hva er din e-postadresse? *

3. Hvor gammel er du? *

4. Hvilket kjønn er du? *

- Mann
- Kvinne
- Annet
- Ønsker ikke å svare

5. Din kode: (den du har fått på en papirlapp) *

Spill og interesser

6. Hvor mange timer spiller du i uka? *

Dette kan være spill på PC, konsoll, mobil og nettbrett.

- ◯ 0 timer
- ◯ 1-5 timer
- ◯ 5-10 timer
- ◯ 10-20 timer
- ◯ 20+ timer

7. Omtrent hvor mange forskjellig videospill har du spilt den siste måneden? *

- ◯ 0 videospill
- ◯ 1-5 videospill
- ◯ 5-10 videospill
- ◯ 10-20 videospill
- ◯ 20+ videospill

8. Hvis du spiller, nevn et par-tre vidoespill du har spilt i det siste.

Spørreundersøkelse
Collective Reasoning

* Obligatorisk

Læring i skolen

9. Hvor ofte opplever du at du enig i disse utsagnene? *

	Aldri eller nesten aldri	Sjeldent eller iblant	Halvparten av tiden	Ofte	Alltid eller nesten alltid
Jeg liker å konstruere teorier for å få rare ting til å gå opp.	○	○	○	○	○
Jeg bruker ikke mer tid på skolearbeid enn det som er nødvendig for å få tilfredsstillende resultat. Jeg vil heller bruke tiden min på andre ting.	○	○	○	○	○
Jeg føler at nesten ethvert emne kan være svært interessant	○	○	○	○	○

	Aldri eller nesten aldri	Sjeldent eller iblant	Halvparten av tiden	Ofte	Alltid eller nesten alltid
når jeg først får satt meg inn i det.					
Jeg kommer til de fleste timene med faglig spørsmål jeg vil ha svar på.	○	○	○	○	○
Jeg ser ikke noe poeng i å lære noe som ikke kommer på prøven.	○	○	○	○	○
Jeg prøver å relatere det jeg lærer i et fag med hva jeg lærer i andre fag.	○	○	○	○	○
Jeg liker fag hvor man bare lærer fakta bedre enn fag som krever mye lesing og forståelse.	○	○	○	○	○
Jeg prøver å relatere nytt materiale, mens jeg leser det, til det jeg allerede vet om emnet.	○	○	○	○	○
Jeg begrenser generelt	○	○	○	○	○

	Aldri eller nesten aldri	Sjeldent eller iblant	Halvparten av tiden	Ofte	Alltid eller nesten alltid
læringsaktiviteten mine til det som er satt opp, da jeg tror det er unødvendig å gjøre noe ekstra.					
Jeg foretrekker oppgaver som spesifiserer nøyaktig hva man skal gjøre.	○	○	○	○	○
Når jeg leser en lærebok prøver jeg å forstå hva forfatteren mener.	○	○	○	○	○
Jeg liker å jobbe nok med et emne til at jeg kan danne egne konklusjoner før jeg sier meg fornløyd.	○	○	○	○	○
Jeg opplever at det holder å pugge viktige deler av pensum, jeg trenger ikke å prøve å forstå de.	○	○	○	○	○

	Aldri eller nesten aldri	Sjeldent eller iblant	Halvparten av tiden	Ofte	Alltid eller nesten alltid
Jeg jobber hardt med skolearbeid fordi jeg synes materialet er interessant.	○	○	○	○	○
Jeg synes ikke lærere bør forvente at elever jobber med tema som er utenfor læreplanen i faget.	○	○	○	○	○
Jeg synes ikke det er nyttig å studere ting i dybden. Man trenger ikke å vite så mye for å gjøre det greit i de fleste fag.	○	○	○	○	○

10. Hvor godt liker du dette faget? *

jeg trenger

Collective Reasoning

11. Hvordan gikk dere fram for å samle og vedlikeholde informasjon i gruppen din? *

12. Hvordan gikk dere fram for å bestemme innhold og struktur til argumentet i gruppen din? *

13. Hva motiverte deg mest til å spille spillet? *

Velg høyst 3 alternativer.

- ☐ Læring
- ☐ Gruppepress eller forventninger fra gruppen
- ☐ Konkurere med andre grupper
- ☐ Samarbeide med andre elever på gruppa
- ☐ Lage argumenter
- ☐ Få fine farger
- ☐ Annet (Utdyp i neste spørsmål)

14. Hvorfor? *

Collective Reasoning tilbakemelding

15. Hvor **artig** synes du spillet var? *

16. Gjerne forklar kort hva som gjorde spillet mer/mindre artig

17. Hvor enkelt var det å bruke spillet? *

18. Gjerne forklar kort hva som gjorde spillet enklere/vanskeligere å bruke

19. I hvor stor grad har du lyst til å benytte spillet igjen til læringsformål? *

Læring i Collective Reasoning

20. Hvor **lærerikt** synes du spillet var? *

21. Gjerne forklar kort hva som gjorde spillet mer/mindre lærererikt

22. Beskriv kort et konsept du kom over mens du spilte som er nytt for deg. *

23. Fra hvilke kilder tilegnet du deg mest nye lærdom? *

Velg høyst 3 alternativer.

- ☐ Dine gruppemedlemmer
- ☐ Lærebook
- ☐ Internett
- ☐ Lærer og andre som vurderte
- ☐ Innholdet av spillet selv (For eksempel Tips&Triks eller strukturen på resonneringsaktiviteten)
- ☐ Annet

24. Hvor lenge tror du at du kommer til å huske kunnskapen du har tilegnet deg i dette spillet i forhold til vanlig undervisning? *

- ○ Mye kortere enn vanlig
- ○ Noe kortere enn vanlig
- ○ Like lenge som vanlig
- ○ Noe lengre enn vanlig
- ○ Mye lengre enn vanlig

H | Questionnaire Elaborations

Table H.1: The original Norwegian elaborations to enjoyment game rating

Enjoyment rating	Elaboration comment
3	det var ikke så mye et spill som en kildekonkurranse, men det var greit
2	litt forvirrende
3	kunne ikke slette før dere hadde lest over så vart litt rotete etter hvert
1	litt kjeelig og mye teori, som gjorde spillet lite praktisk.
3	Spillet var litt kipt
5	konkuransen
2	det var litt for seriøst, lite spillete
4	Artig måte å lære om et tema på. Raskt og effektivt.
3	Mer faktaspill enn et tradisjonelt spill.
2	Faglig og komplisert. Fint konkkuranseaspekt
1	vet ikke
2	Poengsystemet var på sin måte litt vanskelig å forstå.
1	Skjønte ikke helt greia
4	Det var gøy å konkurrere. Men slike spill er kjedelig fra før av
3	Morsomt at det var litt stress.
1	Føler at det ikke kan kalles et spill. Et spill skal være gøy. Mer et tankekart der vi skrev ting.
5	Det var artig med konkuransse, det å jobbe med andre
4	veit ikke
2	Føles ikke ut som et spill når spillet baserer seg på vurderingen til et annet menneske. Det burde vært AI om vurderte alle svar likt. Føles ikke ut som et "spill" i mine øyne heller, trenger at det er karakterer, men dette er vel et læringsspill...
3	Litt vanskelig med å definere hva som er en konklusjon og hva som er fakta
2	Mer artig: Konkurranse, premie og tidsfrist.
4	Det gjorde det artig å få poeng underveis for det ga motivasjon til å skrive utfyllende og presist.
3	mindre: det bugget (mistet dobbelpoeng, men fikk tilbake på slutten). ble lite tid.

Continued on next page

Table H.1: The original Norwegian elaborations to enjoyment game rating (Continued)

3	Hadde vært kult med musikk i bakgrunnen
3	Det er ikke veldig spennende å se på, men score-systemet var bra og gjorde det artig.
3	Vanskelig å si hvor gøy spillet er før vi har fått resultatene, men det var gøy å jobbe i grupper og samarbeide.
4	Vi mistet vår dobbelpoeng og fikk ikke den ikke før slutten.
2	Jeg forsto ikke spillet helt, det var litt forvirrende. Poengsystemet var også litt forvirrende
2	Det var litt forvirrende spill, jeg forsto ikke helt hvordan poengsystemet fungerte.
4	Hadde foretrukket å gjøre det alene
4	for mye arbeid
4	litt vanskelig å vite hva man skulle skrive for å oppnå poeng. Litt stressende.
2	Jeg var lite interessert i temaet/spørsmålet.
5	Det var veldig gøy når man så at man fikk en bra score på det som ble skrevet inn fordi det gir en liten mestringsfølelse.
5	Artig at det er poengsystem og premie
3	Det var et spill om fag så da blir det automatisk mere kjedelig
2	Jeg er usikker.
3	powerups kult
3	Det var litt vanskelig å forstå i starten
4	Jeg er veldig konkurranse innstilt og det er det som gjør spill morsomme for min del.
2	Forsto ikke så mye av det i Sterten, tok litt tid å komme i gang
4	Vet ikke
4	jeg synes det var veldig gøy etter litt når jg forsto det, veldig bra:))))))))))

Note: Ratings without elaborations are not included in this table.

Table H.2: The original Norwegian elaborations to usability game rating

Usability rating	**Elaboration comment**
5	forvirrende med hvordan sammenhengen skulle være men lett å skrive inn informasjon
5	Vet ikke
2	klikket
3	lett overkommelig men en smule rotete i å flytte de ulike boksene
3	Vi fikk ikke til å slette ting
3	litt vanskelig å skjønne når man skulle skrive fakta og når man skulle skrive konklusjon.
4	Vanskelig å forstå forskjellen mellom faktaboks og konklusjonsboks.

Continued on next page

Table H.2: The original Norwegian elaborations to usability game rating (Continued)

3	oversiktlig
4	Lett å samarbeide. Likte ikke at man kunne bare ha to faktabokser på en gang.
1	Komplisert.
1	pcen fryst
3	Kunne vært mulighet for flere bokser samtidig
3	Litt komplisert og vanskelig å komposere argumenter på måten fakta+konk
5	Det var litt irriterende med max to uferdige faktabokser, dette gjorde det vanskeligere når man jobber i større grupper, siden alle kan ikke jobbe induviduellt.
3	Vi forsto ikke at vi ikke kunne endre når det var sendt inn.
1	Vanskelig når vi måtte fullføre hver faktaboks for å skrive nye faktakbokser
4	Det var irriterende at man bare kunne skrive en faktaboks om gangen.
2	Var litt forvirrende her og der
4	Enkle og forståelige knapper
4	Enklere: Ikke så mye som skjedde
4	Det var ganske rett fram hvordan man skulle gjøre de ulike tingene
3	fikk bare ha to faktabokser åpne på samme tid
2	Litt vanskelig å vite hva man skal gjøre, og hvordan man får poeng
4	Det var litt vanskelig at bare to faktaopplysninger kunne skrives samtidig og at man ikke kunne flytte på boksenes plassering. Men ellers var det ikke veldig vanskelig å bruke det når man først hadde forstått hvordan det funket.
3	Noen merkelige ting skjedde underveis. Noen av det jeg skrev forsvant uten at jeg gjorde noe. Ellers var spillet greit.
5	Det var enkelt å finne ut hvordan spillet fungerer.
3	Man kunne ikke redigere det man hadde lagt inn før lærer hadde rettet
2	Man kunne ikke redigere svaret, før de har fått poeng og vurdering på det. Det gjorde spillet litt vanskelig, og det var det som trakk veldig mye i poengene.
4	Det var forvirrende hvordan man skulle strukturere det
3	Skjønte ikke oppbygningen med en gang
4	Godkjenningsprosessen og redigeringen skjønt jeg ikke så mye av.
3	Spillet var enkelt å forstå, men det er mye rom for forbedring.
4	Litt vanskelig at man bare kunne ha to uferdige fakta samtidig fordi vi var 5 på gruppen og da måtte vi andre skrive i word i mens. Jeg skjønner det fordi det kan bli rotete hvis det er fem plasser det står "Ny fakta".
5	Litt mer design så ville det vært strålende!
4	Kunne ha fårr lov og skrive ned mere fakta samtidig
4	Det var ikke så komplisert å gjennomføre.
3	tullete UI
3	Når man først forsto hvordan man gjorde det så var det ganske greit

Continued on next page

Table H.2: The original Norwegian elaborations to usability game rating (Continued)

5	Gjennomgangen før vi startet var fin og det var veldig ryddig og enkelt spill der man bare måtte trykke på boksene.
2	Det var litt lite oversiktlig
4	Vet ikke
5	det var veldig tydelig hva man skulle gjør
1	komplisert oppsett

Note: Ratings without elaborations are not included in this table.

Table H.3: The original Norwegian elaborations to learning outcome game rating

Learning outcome rating	Elaboration comment
5	finne informajsob selv
4	vanskelig å finne alt relevant
4	mye informasjon som man ellers ikke hadde svart på eller tatt med på et så simpelt spørsmål.
2	vanskelig
4	Mye informasjon på kort tid.
2	Vanskelig
2	vet ikke
3	Rar måte å innhente informasjon på. Ved søk eller å lete med tanke på at spillet var tidsbestemt lagde et lite press.
1	søkte alt opp på nettet
3	Jeg skrev ikke alt, dermed har jeg ikke informasjon om alle temaene.
3	Lettere å lære når det er noe morsomt.
1	Du lærer det du selv skriver
5	Det gjorde læring mye mer artig, slik at man ville lære mer.
4	Veit ikke
2	Ikke et nytt emne, kunne ha utfordret oss til noe nytt.
5	Siden vi er mange blir ikke alle med på alle boksene og dermed lærer ikke alt som er med.
3	Mer: Man finner jo svaret på spørsmålet
4	Måtte komme med mange faktorer og koble det opp mot et spesifikt tema, som gjorde at man måtte få en grundig forståelse
4	det var et stort tankekart som er nyttig
3	Det handler mer om å oppsummere ting man allerede vet, og det er vanskelig å vite hva som er relevant.
3	Det at vi ikke fikk så god tid gjorde at vi ikke hadde mulighet til å tenke gjennom alt like mye og det ble tatt en mer forhastet konklusjon som gjorde at vi ikke fikk tenkt og reflektert så mye.
2	Kan være litt vanskelig å lære når spillet må gjennomføres såpass fort.

Continued on next page

Table H.3: The original Norwegian elaborations to learning outcome game rating (Continued)

5	Vi fant fakta om et tema som vi gikk utdype oss i.
2	Vi fikk ikke tid til å finne så mye informasjon, og det var generelt lite man kunne skrive om spørsmålet.
2	Jeg synes at det er akkurat som en vanlig undervisning for oss, men litt unødvendig for å lære nye ting, fordi vi søke på internett eller i boka for informasjon.
3	jo flere man er på gruppen, desto vanskeligere er det å få med seg alt som skjer
4	Fikk mulighet til å svare på spørsmål ved å finne fakta som kunne bygge opp begrunnelser til et endelig svar.
4	For å få et høyt poengsum må en samle inn og formulere presis, relevant informasjon.
5	Vi måtte lese og forstå innholdet for at vi skulle kunne skrivet gode svar
4	Spilelt baserer seg på historie og emner som er fint å lære om
3	Det var for det meste informasjon man allerede viste
4	Tenkte mer.
4	Man vil gjøre det bra og da plukker man også lettere opp på informasjon.
3	Spilet var lærerikt
4	Du gjør din egen forskning på temaet.
5	Når man får snakket med andre om ting så lærer jeg mere
2	får samarbeide

Note: Ratings without elaborations are not included in this table.

Table H.4: The original Norwegian motivation sources and elaboration

Motivation sources	**Elaboration**
Konkurere med andre grupper;	konkurranseinstinkt
Få fine farger;Konkurere med andre grupper;	jeg liker fine farger
Konkurere med andre grupper;	bli best
Annet (Utdyp i neste spørsmål);Konkurere med andre grupper;	KONKURANSE INNSTINKT
Konkurere med andre grupper;	jeg liker å vinne
Annet (Utdyp i neste spørsmål);	Jeg ville ha NTNU merch.
Læring;Samarbeide med andre elever på gruppa;	Usikker
Konkurere med andre grupper;	fordi jeg vil vinne over klassekameratene mine
Konkurere med andre grupper;Annet (Utdyp i neste spørsmål);	Det som motiverte meg mest var å vinne merch.
Få fine farger;Konkurere med andre grupper;Samarbeide med andre elever på gruppa;	Konkuranseinnstingt

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Table H.4: The original Norwegian motivation sources and elaboration (Continued)

Konkurere med andre grupper;Samarbeide med andre elever på gruppa;	Konkurranseinstinkt er noe de fleste har, spesielt oss. Gøy å samarbeide med andre for å slå resten.
Konkurere med andre grupper;	Konkurranseinnstinkt. Må vinne.
Få fine farger;Annet (Utdyp i neste spørsmål);	vi mått:)
Læring;Samarbeide med andre elever på gruppa;Konkurere med andre grupper;	Fordi det er gøy
Konkurere med andre grupper;Gruppepress eller forventninger fra gruppen;Samarbeide med andre elever på gruppa;	Forventning om å prøve å få det til og det fungerte godt å samarbeide
Gruppepress eller forventninger fra gruppen;Konkurere med andre grupper;	Vet ikke
Konkurere med andre grupper;	Det er gøy å konkurrere med andre.
Konkurere med andre grupper;	Det er morsomt med konkurranser.
Konkurere med andre grupper;	Det er gøy
Konkurere med andre grupper;Få fine farger;Læring;	Gøy med slike konkurannser siden det skaper mer konkurannse innstinkt.
Læring;Konkurere med andre grupper;Samarbeide med andre elever på gruppa;	Fordi det er arti å jobbe på grupper med andre elever og å konkurrere med resten
Få fine farger;Annet (Utdyp i neste spørsmål);Konkurere med andre grupper;	Vinne over alle slik at de taper, ikke slik at jeg vinner.
Konkurere med andre grupper;	Og premie
Konkurere med andre grupper;Samarbeide med andre elever på gruppa;Lage argumenter;	Liker å konkurrere
Læring;Konkurere med andre grupper;	fordi vi skulle bruke timen på dette
Samarbeide med andre elever på gruppa;	Fordi det er et godt redskap for læring.
Annet (Utdyp i neste spørsmål);	Historie time
Konkurere med andre grupper;Samarbeide med andre elever på gruppa;Gruppepress eller forventninger fra gruppen;	Jeg har fått utrykt hvorfor i avkrysningen ovenfor.
Samarbeide med andre elever på gruppa;Konkurere med andre grupper;Annet (Utdyp i neste spørsmål);	Å vinne
Gruppepress eller forventninger fra gruppen;Samarbeide med andre elever på gruppa;	Det var interessant.
Læring;Få fine farger;	Konkurranseinnstinkt :)
Annet (Utdyp i neste spørsmål);Få fine farger;Læring;	vil vinn:D
Få fine farger;	Fine farger = happy
Samarbeide med andre elever på gruppa;Konkurere med andre grupper;Læring;	Det er gøy å jobbe med andre. Veldig koselig :)
Læring;Konkurere med andre grupper;Samarbeide med andre elever på gruppa;	Når man først spiller et spill i timen, vil jeg helst bruke det til å lære noe om faget
Læring;Gruppepress eller forventninger fra gruppen;	Fordi man vil ikke at det skal gå ut over de andre om man gjør det dårlig

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Table H.4: The original Norwegian motivation sources and elaboration (Continued)

Gruppepress eller forventninger fra gruppen;	Jeg har lite konkurranseinstinkt, men prøver mitt beste for å oppfylle forventninger fra andre.
Konkurere med andre grupper;Samarbeide med andre elever på gruppa;Lage argumenter;	Jeg er veldig glad i konkurranse, og hvis jeg skal være helt ærlig tenkte jeg ikke over at jeg faktisk lærte noe før i ettertid. Jeg likte dette veldig godt. Jeg er også glad i å komme med argumenter som viser at andre har feil samt at jeg selv har riktig. Jeg driver med lagsport og synes at samarbeid er veldig gøy. Jeg vil gjøre det best mulig for de andre.
Læring;Konkurere med andre grupper;	konkuranseinnstinkt
Gruppepress eller forventninger fra gruppen;	Jeg liker gruppepress, det gir meg motivasjon og konsentrasjon
Annet (Utdyp i neste spørsmål);	fordi jeg måtte?
Samarbeide med andre elever på gruppa;	Synes det er artigst
Konkurere med andre grupper;Samarbeide med andre elever på gruppa;	Det er gøy å samarbeide også er det gøy å konkurere litt
Konkurere med andre grupper;	Det er gøy å konkurrere mot de andre i klassen
Samarbeide med andre elever på gruppa;Få fine farger;Læring;	Historie er gøy
Konkurere med andre grupper;Samarbeide med andre elever på gruppa;Læring;	jeg liker konkuranse, snakke med andre i klassen og læring på en gøy måte.
Læring;	jeg vil lære

Note: Motivation sources without elaborations are not included in this table.

I Raw Argument Graph Analysis

Table I.1: Classification and scores of support relations in the argument graphs of each city.

Group name	**Total score**	
Relation name	**Code**	**Score**
Aten1	**0.25**	
Norge ble sett på som en selvstendig nasjon	G3	0.5
Norges første forsvar etter grunnloven ble skrevet	G1	0
Kieltraktaten	G3	0.5
Norges egen grunnlov 1814	G3	0.5
Språk	G2	0
Napoleonskrigene	G2	0
Løslatelse av Dannmark til svar	G5	
Til løslatelse av Dannmark	G6	
Egina1	**0.5**	
Napoleonskrigene	G4	1
Kieltraktatens konsekvenser	G1	0
Ny union mer frihet	G1	0
Union med Sverige	G3	0.5
Til Norges grunnlag	G4	1
Fra Norges grunnlag	G3	0.5
Til industrielle revolusjonen	G1	0
Fra industrielle revolusjon	G4	1
IndRev påvirkning	G5	
Rodos1	**0.65**	
Napoleonskrigens	G4	1
Handel	G4	1
Økende nasjonalisme	G3	0.5
Utdannelse til bondestortinget	G2	0
Fra bondestortinget	G2	0
Konklusjon	G5	
Udannelse til selvstendighet	G4	1

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Table I.1: Classification and scores of support relations in the argument graphs of each city. (Continued)

Group name	**Total score**	
Relation name	**Code**	**Score**
Overført til sverige	G4	1
Selvstendig	G4	1
Pressefrihet	G1	0
Unionstid	G4	1
Sparta1	**0.14**	
Jordbrukssamfunnet	G1	0
Bygger nasjon	G1	0
Endring i levemåte	G1	0
Napoleonskrigene	G3	0.5
Christian Fredrik	G1	0
Europeiske opplysningstiden	G1	0
Fredsavtale	G3	0.5
Aten2	**0.60**	
Norge egen stat	G1	0
Napoleonskrigen	G3	0.5
Kieltraktaten	G4	1
Nasjonalromantikken	G4	1
Grunnloven	G3	0.5
Frigjøringen	G6	
Egina2	**0.42**	
Den franske revolusjonen til nasjonal bevegelse	G4	1
Nasjonal bevegelse	G3	0.5
Den franske revolusjonen til oppløsning av union	G3	0.5
Norge avgitt til oppløsning av union	G3	0.5
Til levstandaren økte	G1	0
Til svar	G6	
Til skriftspråk	G2	0
Korint2	**0.42**	
Økt nasjonalfølelse	G3	0.5
Nytt skriftspråk	G3	0.5
Nasjonalromantikken	G1	0
Statsmakter og pengevesen	G1	0
Napoleonskrigen	G4	1
Union med Sverige	G6	
Unioner	G3	0.5
Rodos2	**0.50**	

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Table I.1: Classification and scores of support relations in the argument graphs of each city. (Continued)

Group name	Total score	
Relation name	**Code**	**Score**
Stormannsmøte	G4	1
Riksforsamlingen	G3	0.5
Grunnlov	G3	0.5
Opprør i Norge	G2	0
Nasjonalisme	G3	0.5
Nasjonalfølelsen	G4	1
Avgitt til Sverige	G3	0.5
Sverige mente Norge selvstendig	G3	0.5
Go Sverige!!!!	G2	0
Sparta2	**0.60**	
Grunnloven	G4	1
Nasjonalromantikken	G4	1
Dannelse av politiske partier	G3	0.5
Økonomisk fremgang	G3	0.5
Eget skriftspråk	G2	0
Økt selvstendighet	G6	
Aten3	**0.43**	
Undertrykkelse	G6	
Undertrykking	G3	0.5
Store dødstall	G6	
Erobring av landområder	G2	0
Europerene slaver	G4	1
Amerika stammer fra afrika	G1	0
Sykdommer i større	G4	1
Befolkninger utslettes	G3	0.5
Sykdommer sprer seg	G1	0
Egina3	**0.13**	
Inflytelse til Nato	G2	0
Inflytelse til militær	G2	0
Inflytelse til svar	G1	0
Nato til miltær	G3	0.5
Nato til fred	G2	0
Fred til militær	G1	0
Fred til svar	G2	0
Sykdommer til urbefolkning	G3	0.5
Sykdommer til svar	G3	0.5

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Table I.1: Classification and scores of support relations in the argument graphs of each city. (Continued)

Group name	Total score	
Relation name	**Code**	**Score**
Språk til urbefolkning	G2	0
Språk til svar	G2	0
Mer resusser	G1	0
Resusser	G1	0
Slaveri	G0	0
Kalde krigen	G0	0
Spansk kolonisering til uavhengighet	G1	0
Spansk kolonisering til svar	G3	0.5
Uavhengighet	G2	0
Språk	G2	0
Thanos	G3	0.5
Rodos3	**0.33**	
Mange liv ble tapt	G1	0
Mange millioner døde	G3	0.5
Utsettelse	G6	
Utrydelse	G6	
Slaveri	G4	1
Europa fysisk motstand	G0	0
Konklusjon språk	G6	
Språk	G1	0
Presset urbefolkning	G3	0.5
Sykdommer i Europa	G3	0.5
Konklusjon ressurser	G6	
Ressurser i Amerika	G1	0
Ressurser	G3	0.5
Sparta3	**0.5**	
Handel til handel i amerika	G4	1
Handel til svar	G5	
Konsekvenser for urbefolkningen	G6	
Amerikaske revolusjon	G2	0
Borgerkrigen til slavearbeid	G1	0
Slavearbeid	G1	0
Utnyttelse av landet	G3	0.5
Den amerikanske urbefolkningen	G4	1
Millioner døde	G4	1

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