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Comparing the effectiveness of online and face-to-face debate games

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Abstract

Debate games offer a stimulating educational tool, promoting critical thinking, communication skills, and knowledge acquisition. The rise of online learning platforms necessitates exploring the effectiveness of online debate games compared to their traditional face-to-face counterparts. This research investigates this very question, focusing on motivational and communication aspects.

We examine the effectiveness of online and face-to-face debate games in promoting learning outcomes. The Phosphorus Negotiation Game (P-Game), a serious game centered on sustainable phosphorus management, serves as the research framework. Participants in both online and face-to-face settings engaged in British Parliamentary System (BPS) debates, and their experiences were evaluated using pre- and post-game surveys alongside the System Usability Scale (SUS) for the online format. This study compares the effectiveness of online and face-to-face debate games in terms of knowledge gain, motivation, and communication patterns. The findings contribute to the understanding of online vs. face-to-face learning environments within the context of debate games, offering valuable insights for educators and developers of online learning platforms.

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1. Introduction

Debate games offer a valuable educational tool, fostering critical thinking, communication skills, and knowledge acquisition. The growing trend of online learning platforms necessitates exploring the effectiveness of online debate games compared to their traditional face-to-face counterparts. This research investigates this very question, particularly focusing on motivational and communication aspects.

Research question: How do online and face-to-face debate games compare in terms of effectiveness in promoting learning outcomes, while considering motivational and communication aspects?

Structure: This paper is divided into five sections. Following this introduction, a review of relevant literature will explore serious games, the P-Game (a specific example of a serious game focused on sustainable phosphorus management), and existing research on online vs. face-to-face learning environments. The methodology section details the research design, including the evaluation tools employed. The results section will present findings from both online and face-to-face debate game tests, with separate sections for clarity. Finally, the discussion section will interpret the results, address limitations, and suggest areas for future research. The conclusion will summarize key findings, restate the research question with a concluding statement, and discuss the implications for educators and online learning platform developers.

This research leverages the P-Game as a framework for both online and face-to-face testing. The P-Game utilizes the British Parliamentary Style (BPS) debate format, tasking participants with arguing a predetermined motion related to sustainable phosphorus management. The research analyzes data from pre- and post-game surveys designed to assess knowledge gain and engagement, along with the System Usability Scale (SUS) for the online format to evaluate user experience.

2. Literature Review

To understand the effectiveness of online and face-to-face debate games, this section explores relevant literature. First, we examine the concept of serious games, including their educational value and design principles. Second, we delve into the P-Game, a specific serious game focused on sustainable phosphorus management. Finally, we review existing research comparing online and face-to-face learning environments, particularly regarding motivation and communication aspects. This review will provide a foundation for analyzing the effectiveness of online vs. face-to-face debate games in promoting learning outcomes.

2.1 Serious game

Serious games were first defined by Abt, as follows: “games that do not have entertainment, enjoyment, or fun as their primary purpose” [1]. They are developed to accomplish particular objectives. These objectives can be education, training, or behavior change. Serious games can be used to imitate or even simulate real-world scenarios, giving students a safe and controlled environment to practice their abilities and make judgments.

Serious games consist of three elements [2]:

1. Experience: Serious games provide players with an experience related to a specific context, such as well-being, education, or health.
2. Entertainment: While not the primary focus, entertainment is still a dimension incorporated in serious games.
3. Multimedia: Serious games leverage a combination of media formats like text, graphics, animations, audio, and haptics to deliver the experience and content.

Serious game is an interactive application that seamlessly blends an educational or purposeful experience with engaging entertainment, all delivered through a combination of multimedia elements like text, visuals, sound, and potentially even touch feedback.

There was a significant growth in both research and actual usage of serious games in the industry in the XXI century. The topic is still significant however there is a slowdown in the published papers (see at Figure 1). The graph in Figure 1 was drawn from data collected by [3] which script states that “This script extracts the historic word occurrence of a search term in academic papers (from Google Scholar). It allows for spotting trends in research and analyzing

the relevance of a topic over time.”. The data suggests a sustained interest in Serious games within research papers, with consistent mentions over the past two decades. The recent dip in 2024 might indicate a shift in research focus, potentially towards new applications inspired by the groundwork laid by Serious games.

serious game publications

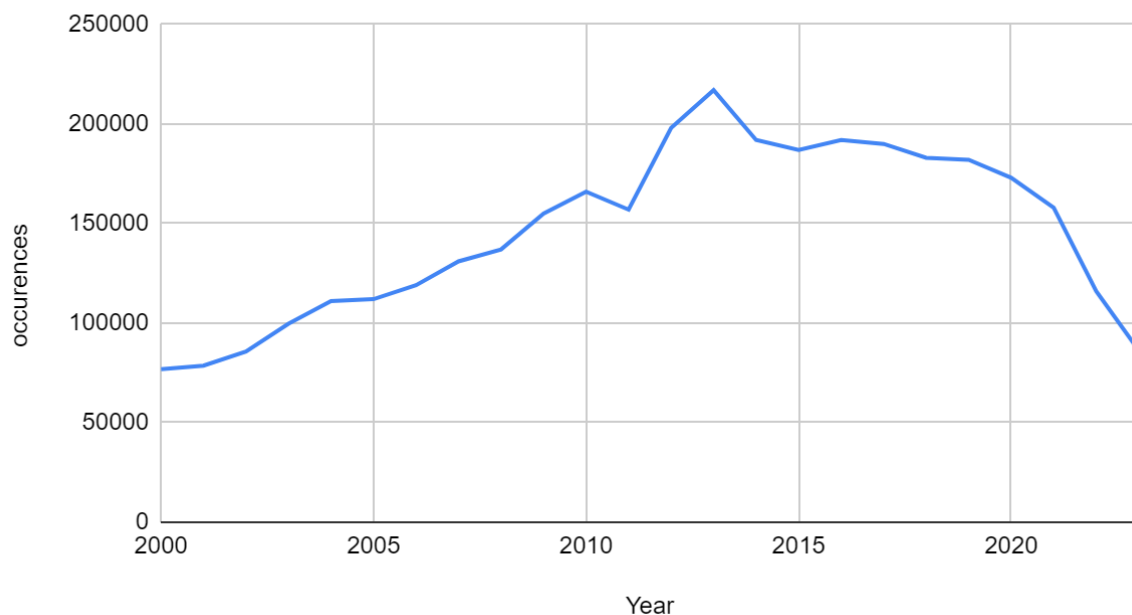


Figure 1 serious game publications over the years

As mentioned above, multimedia is an important part of serious games, video games also leverage multimedia to create an immersive, engaging design. Opening new possibilities for interactive learning experiences that are both educational and enjoyable. Minnesota Educational Computing Consortium (MECC) were among the first producers of digital format educational games such as Lemonade Stand and The Oregon Trail [2].

We can draw the conclusion that serious games have the potential to impact the field of education, advertising and healthcare resulting in various degree of improvements.

2.2 Debating

There are numerous and diverse forms of discourse and argumentation, commonly known as debating, they differ from one region to another. In this particular segment

of our comprehensive analysis, we discuss the fundamentals and essential components.

2.2.1 Differences between regions

The most well-known formats are the Australian, the Asian and the British parliamentary formats. The main difference is in the Australasian/Asian format there are two teams in the British parliamentary debates there are four teams. This difference in team member count also reflected in the method of assessment as we distinguish between 1st, 2nd, 3rd and 4th debaters. Adjudicators will rank them separately, making the debate more competitive, individually motivated. The points are added up per side to give the winner.

The British evaluation is also different from the others where judges evaluate the debate together, in contrast each of the adjudicators tentative ranking. This provides that the influence of each other can be minimized. After individual evaluations they discuss it to reach a final overall score.

“Adjudicating debates is a subjective exercise. Unlike many sports, in debates there is no clear method of proving a team’s score. Adjudicators, quite often, are equally divided as to the winner of a debate, particularly in very close ones.” [20]

2.2.2 History of English parliamentary system

One of the most important aspects of the UK Parliament's operation is its debate system. Members of Parliament (MPs) can examine government policy, voice their opinions, and hold the administration responsible through debates in both the House of Commons and the House of Lords. Rules and procedures are closely followed during the debating process to ensure that each member has an equal chance to participate. MPs frequently engage in intense arguments and lively discussions during the debates.[21]

A motion—also known as a proposal—is made during a discussion by an MP or a member of the House of Lords. Afterwards, the motion is discussed, and peers or MPs are given the chance to argue for or against it. Opening statements, counterstatements, and closing statements are all part of the debates' predetermined format. It is not permitted to interrupt MPs or peers during their allotted speaking time.[22]

For being fair and impartial, the UK Parliament's debating process has received praise. A report by the Hansard Society [23] claims that the UK Parliament's debating methodology is one of the most open and transparent in the entire world. Additionally, the report noted that the debates give MPs a chance to participate.

In summary, a key component of the UK's democratic process is the debate mechanism used in the parliament. It enables lawmakers to examine government policy, voice their opinions, and demand accountability from the executive branch. Rules and procedures are closely followed during the debates to ensure that everyone has an equal chance to participate. The debating process used in the UK Parliament is largely considered as fair and neutral, offering a great forum for productive discussion and debate.

2.3 The Phosphorus Negotiation Game (P-Game)

The P-game is heavily inspired by the game called Mercury game by Stokes and Selin. The game was a negotiation simulation that immerse the participants in a scenario where they are assigned a task with making informed decisions in the context of science-policy interactions at Harvard Law School and the Massachusetts Institute of Technology at the beginning of the 2010s. This was a simulation where participants engage with real-world challenges related to environmental mercury contamination, participants can experience the challenges and difficulties that decision-makers experience. [4]

As discussed earlier serious games have a huge potential and the mercury game showed us that it's proven to be an important contribution in environmental negotiations even more. Participants in this simulation put themselves in the shoes of policymakers by tackling role-playing exercises that weighed scientific evidence, economic realities, stakeholder needs, and ethical dilemmas. After the simulation wrapped up, the evaluation showed that participants didn't just gain a greater appreciation for the challenges of negotiating science-based policies, but they also walked away with sharper negotiation skills and a better understanding of navigating conflicting interests – all crucial skills for anyone working in environmental governance. [4]

These results have led to a new adaptation of the mercury game, this is a serious environmental role-play simulation, or serious game on sustainable phosphorus (P) production the “P-Game”, or phosphorus negotiation game. “Phosphorus is an essential element to all living beings. It is finite, and mining as well as processing it is complex, affecting numerous Sustainable

Development Goals (SDGs) of the United Nations so that several research groups have called for innovative approaches to improve our understanding of phosphorus production. Following feedback from Stokes and Selin the P-Game was played with students that have different educational (science and social science) as well as cultural backgrounds.” [4]

There were some shortcomings of the previous games that P-game aims to solve one of these problems where the game simulation often requires huge amounts of preparation of the participants before the game that can take several weeks. P-Game created a much handier serious game that can be played within 2-3 hours without any preparation of the participants. The duration of the P-Game relatively short for two purposes. Firstly, it’s aimed to create a game that could be seamlessly incorporated into existing courses, occupying no more than a single lecture (maximum 3 hours). Secondly, it’s aimed for simplicity to enable the future digitization of the game, facilitating virtual play. Preliminary results for the virtual P-Game are currently under development. We believe that for a smartphone-based game, a shorter duration is essential to engage and attract participants effectively. This project took a different approach compared to existing serious games in the phosphate industry. The main goal at this stage wasn't to further educate industry experts. Instead, we wanted to evaluate the effectiveness of the game's design itself. In particular the focus was whether participants gained new knowledge and if the game played smoothly without any glitches. [4]

2.3.1 Offline methodology

P-game has been played in 18 countries and with almost 600 participants. This widespread reach allows us to analyze its effectiveness across diverse settings figure 1 provides an overview on how the P-Game was played at the different institutions [4].

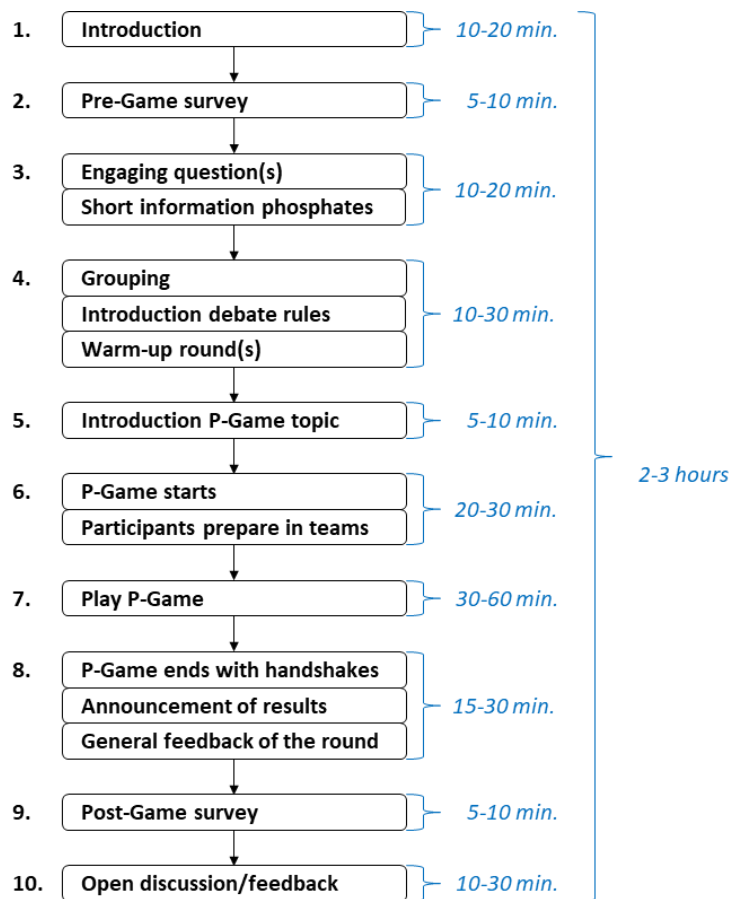


Figure 2. Overview on how the P-Game was played. [4]

To ensure a level playing field, participants were informed they would play a role-playing game about cleaner fertilizer production, without revealing the specific focus on phosphorus. The session began with introductions from the moderators and a brief explanation of the project's origins that led to the game's development (lasting 10-20 minutes using slides). Following this, participants completed pre-game surveys (Figure 4.1) to capture their initial expectations and knowledge base. Similar post-game surveys (Figure 4.2) allowed them to reflect on their experience and whether their expectations were met [4]. Open-ended questions were then posed by the moderators to encourage participation, particularly from those who might be initially hesitant (Figure 2. 3rd step). This served two purposes: - to gauge the participants' existing knowledge of the phosphate industry and negotiation science, and - to identify potential leaders who could take on more active roles in future iterations of the game. For example, a common question involved estimating global phosphate ore production, a key material for fertilizers. After several guesses, the moderators would provide an explanation, often surprising participants, by revealing that phosphate ore ranks among the top five most mined materials globally, with significant uncertainties around reported production figures. This approach aimed to stimulate curiosity and highlight knowledge gaps [4].

The moderators then explained how phosphate ore, mined for its vital plant nutrient phosphorus, underpins modern food production. However, large-scale mining also creates a significant environmental footprint, posing the first dilemma of the game: balancing food security with environmental impact.

After thought-provoking questions and a brief introduction to phosphates (step 4 in Fig. 2), participants formed teams and learned about the BPS debate format (Fig. 3). Warm-up rounds with light topics (10-30 seconds) ensured everyone understood the format before tackling the serious debate [4].

The P-Game adopted the British Parliamentary Style (BPS) debate format (explained in Fig 3), a popular choice in university competitions. BPS features proposition and opposition teams arguing a predetermined motion (like sustainable phosphorus management in our case) with judges and allotted speaking times. While traditional BPS uses 7-minute speeches and 15-minute prep, the P-Game opted for shorter 5-minute speeches and a more generous 20-30 minutes of preparation with online resources allowed. Teams had a minimum of 2 speakers, with additional team members supporting research and participating in the discussion (completing surveys as well) [4].

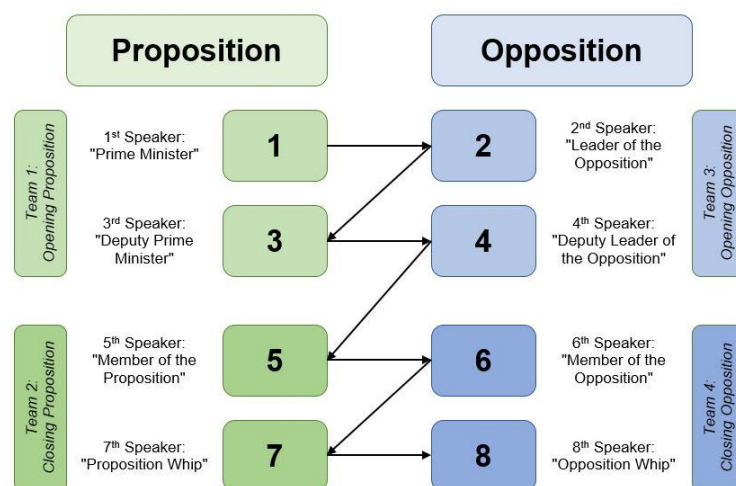


Figure 3. Overview of British Parliamentary Style (BPS) Debating that provided a blueprint for the P-Game. [4]

To enhance engagement, the P-Game concluded with a team ranking and a handshake between participants. This symbolized respectful disagreement, as students often argued viewpoints differing from their own. The handshake also marked the game's end, followed by moderator feedback on arguments and team interaction (15-30 minutes). Finally, participants completed post-game surveys [4].

2.3.2 Online methodology

This study proposes an online adaptation of a game experience designed to improve user experience through streamlined gameplay. The online method leverages the inherent advantages of digital platforms to significantly reduce the time required to inform users. All relevant information regarding the game's mechanics and objectives can be embedded directly within the application, allowing users to access and review instructions at their own pace. This eliminates the need for dedicated instructional phases often present in the original offline version (refer to Figure 2 for a detailed breakdown of these steps: 3. Engaging questions, information of the phosphates, 4. grouping since it's automatic, 8. handshake and feedback since the players rate each other it is also instant). By removing these steps, the online version facilitates a more focused experience centered on the core gameplay elements. This streamlining is anticipated to result in a time reduction of approximately 35-140 minutes compared to the offline version. Importantly, beyond these procedural changes, the core gameplay mechanics remain identical, ensuring a consistent experience for users transitioning between platforms.

2.4 Testing

This chapter explores the distinct challenges associated with providing feedback in online and face-to-face learning environments. While both methods offer unique advantages for instruction, they present contrasting opportunities and limitations regarding student feedback. This section delves into these disparities, highlighting the importance of a comprehensive approach that leverages the strengths of both online and offline communication.

2.4.1 Challenges

To compare Online and face-to-face (F2F) methods we are presented with numerous of challenges in terms of feedback. One of the key drawbacks of online classes compared to F2F classes is the limited opportunity for immediate, informal feedback. The physical distance and different time zones can make it difficult for students to spontaneously ask questions or clarify doubts during lectures. This often necessitates scheduling appointments with professors, which can introduce delays in receiving feedback [7]. Because of that lecturers can prevent misunderstandings in the future, bring new iterations to life quickly. In contrast online classes primarily rely on asynchronous communication through emails, video calls, and discussion forums. Therefore, the introduction of new improvements may be delayed.

However, online communication also offers some unique advantages for feedback. Online platforms allow students to clearly articulate their questions and revisit the information for future reference.

Our findings suggest that relying solely on traditional, immediate in-class feedback or individual online problem-solving exercises may not provide a sufficiently comprehensive picture of student learning. To gain a more holistic understanding of student needs and learning outcomes, a unified survey instrument may be necessary.

2.4.2 Previous testing method offline settings in P-game

Participants completed pre-game surveys (Figure 4.1) to capture their initial expectations and knowledge base. Similar post-game surveys (Figure 4.2) allowed them to reflect on their experience and whether their expectations were met. [4]

Pre P-Game Survey

Do you consider yourself a science or social science student?	Science ☐		Social Science ☐		
What is your major?					
What is your level of education?	BSc- Student ☐	MSc- Student ☐	PhD- Student ☐	PhD Awarded ☐	
Gender	Male ☐		Female ☐		Other ☐
Age group	<20 ☐	20-25 ☐	25-30 ☐	30-35 ☐	>35 ☐
Nationality					
Country of residence					
How would you rate your knowledge of Phosphorus Science? (from 1, very poor/little – to 5 very good/much) – write number	1	2	3	4	5
How would you rate your knowledge of Negotiation Science/Practice? (from 1, very poor/little – to 5 very good/much) – write number	1	2	3	4	5
Date					
What would you like to learn about Phosphorus Science and/or Negotiation Science/Practice? (open answer)					

Figure 4.1 Pre-and post-game surveys used for participants' self-assessments. [4]

Post P-Game Survey

Do you consider yourself a science or social science student?	Science ☐		Social Science ☐		
What is your major?					
What is your level of education?	BSc- Student ☐	MSc- Student ☐	PhD- Student ☐	PhD Awarded ☐	
Gender	Male ☐		Female ☐		Other ☐
Age group	<20 ☐	20-25 ☐	25-30 ☐	30-35 ☐	>35 ☐
Nationality					
Country of residence					
How would you rate your knowledge of Phosphorus Science? <i>(from 1, very poor/little – to 5 very good/much) – write number</i>	1	2	3	4	5
How would you rate your knowledge of Negotiation Science/Practice? <i>(from 1, very poor/little – to 5 very good/much) – write number</i>	1	2	3	4	5
How much and what do you think you learned about Phosphorus Science <i>(open answer)</i>					
How much and what do you think you learned about Negotiation Science/Practice? <i>(open answer)</i>					

Figure 4.2 Post-game surveys used for participants' self-assessments. [4]

This questionnaire been used in the in-person evaluation and more than 300 players filled it out [4]. Evaluate effective tests for open-ended questions can be a challenge. Unlike multiple-choice questions with defined answer options. Factors like interpretation, phrasing, and depth of knowledge can all influence student responses, making it difficult to establish a single "correct" answer.

2.4.3 Previous testing method in the field

Through we research, I've come across various techniques like functionality testing, compatibility testing, and regression testing.

The study [5] researchers used a quasi-experimental design to compare the effectiveness of video-based learning and game-based learning for teaching software design principles.

Students were divided into a control group and an experimental group. The control group learned from short video recordings, while the experimental group played an educational video game. Both groups took a pre-test to assess their prior knowledge and a post-test to measure their learning after the intervention. The tests focused on the SOLID principles (single responsibility, open–closed, Liskov substitution, interface segregation, and dependency inversion). All materials were delivered online through a learning platform. Additionally, a questionnaire was used to gather student feedback on the learning methods.

I considered using the Mann-Whitney U Test for my analysis. This test, developed in 1947, is a popular non-parametric option for comparing two independent groups when the data isn't normally distributed. Similarly, the Kruskal-Wallis Test, an extension of the Mann-Whitney U Test, emerged as a potential option. This non-parametric test serves as an alternative to one-way ANOVA, not requiring assumptions like normal distribution or homogeneity of variance. Both tests aim to identify significant differences between groups, but the Kruskal-Wallis Test relies on ranking data [8].

While these non-parametric approaches offer advantages in certain situations, the t-test's focus on means better suited the needs of my current analysis. A t-test is an inferential statistic used to determine if there is a significant difference between the means of two groups and how they are related. T-tests are used when the data sets follow a normal distribution and have unknown variances. The t-test is a test used for hypothesis testing in statistics and uses the t-statistic, the t-distribution values, and the degrees of freedom to determine statistical significance [9]. The t-test directly compares means, it provided a more targeted approach to my research question, which focused on identifying potential mean differences between the two groups under study.

2.4.4 Usability scale

Traditional usability testing can be complex and require specialized knowledge. To address this, researchers developed the System Usability Scale (SUS), a simple 10-item questionnaire that provides a general sense of user experience. [6]

The SUS leverages a specific type of scale called a Likert scale. While a Likert scale typically presents statements and asks respondents to choose their level of agreement, constructing an effective version requires careful selection of these statements. The best statements evoke extreme reactions on opposite ends of the spectrum, ensuring clear differentiation between positive and negative user experiences. To achieve this, researchers

create a large pool of statements and test them on sample audiences that can be seen on Figure 5. Items with strong agreement or disagreement across respondents are chosen, creating a scale sensitive to user sentiment. The SUS itself was developed using this method, resulting in a set of statements that effectively captures various aspects of usability, such as the need for training or the complexity of the system. [6]

System Usability Scale

© Digital Equipment Corporation, 1986.

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	☐	☐	☐	☐	☐
	1	2	3	4	5
2. I found the system unnecessarily complex	☐	☐	☐	☐	☐
	1	2	3	4	5
3. I thought the system was easy to use	☐	☐	☐	☐	☐
	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
	1	2	3	4	5
5. I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
	1	2	3	4	5
6. I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
	1	2	3	4	5
8. I found the system very cumbersome to use	☐	☐	☐	☐	☐
	1	2	3	4	5
9. I felt very confident using the system	☐	☐	☐	☐	☐
	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐
	1	2	3	4	5

Figure 5 System Usability Scale

3. Methodology

3.1 Development of P-game online adaptation

For the comparison of the games, it was necessary to develop the online adaptation.

This section details the technologies used to develop the cross-platform P-Game application.

3.1.1 Technologies

Flutter (Section 3.1.1.1): An open-source framework by Google for building beautiful, native-feeling applications that run on various platforms (iOS, Android, web, desktop) from a single codebase. Its key advantages include accessibility features, modern UI capabilities, fast performance, and pre-built packages for common development tasks.

Dart (Section 3.1.1.2): The programming language upon which Flutter is built. It offers high performance due to native code compilation, cross-platform support, strong typing for early error detection, and a rich library ecosystem for common functionalities.

Firebase (Section 3.1.1.3): Google's mobile and web application development platform that provides backend services for app creation, user authentication, and real-time data management. It offers a suite of services like Cloud Firestore (real-time data), Cloud Functions (backend processes), Authentication (secure user login), Cloud Storage (file storage), and Realtime Database (cloud-based JSON data storage). Firebase simplifies app development with easy-to-use tools, scalability, real-time data synchronization, comprehensive documentation, and a supportive developer community.

3.1.1.1 Flutter

“Flutter is an open-source framework by Google for building beautiful, natively compiled, multi-platform applications from a single codebase.” [10]

Flutter is a mobile app SDK that enables programmers to create powerful and engaging mobile applications for multiple platforms with a single codebase. Its reactive programming model and use of the Skia rendering engine provide fast and smooth animations and transitions, making it ideal for creating modern and responsive user interfaces.

With Flutter, you can create apps for iOS, Android, desktop, and the web. Furthermore, its pre-built packages for typical app development activities can help you save time and effort. Flutter also comes with tools and accessibility widgets that make it simpler to create apps that are accessible to everyone, including those with disabilities.

The Flutter Framework layer, Flutter Engine layer, Platform layer, and Dart Runtime layer are the four levels that constitute the Flutter architecture. This architecture offers a strong foundation on which to build cutting-edge, high-performance, cross-platform mobile applications. [11]

Key advantages of using Flutter in this project:

1. **Accessibility:** Flutter includes accessibility widgets and tools that help you build apps that are accessible to all users, including those with disabilities.
2. **Modern UI:** Flutter provides a rich set of pre-built widgets and tools that enable you to create modern and engaging user interfaces for your app.
3. **Fast Performance:** Flutter's reactive programming model and use of the Skia rendering engine provide fast and smooth animations and transitions.
4. **Multiplatform Support:** Flutter allows you to develop apps for multiple platforms, including iOS, Android, desktop, and web, using a single codebase.
5. **Easy to Learn:** If you already have knowledge of the Dart programming language, then Flutter is an easy framework to pick up, as it is built on top of Dart.
6. **Pre-Built Packages:** Flutter includes many pre-built packages for common app development tasks, such as HTTP networking, state management, and animation, which can save you time and effort in developing your app.

Overall, Flutter is a great choice for developing mobile apps because of its pre-built packages, modern UI, quick performance, support for several platforms, and accessibility features. Its architecture offers a strong foundation for creating top-notch programs that can give customers a seamless experience.

3.1.1.2 Dart

“Dart is a client-optimized language for developing fast apps on any platform. Its goal is to offer the most productive programming language for multi-platform development, paired with a flexible execution runtime platform for app frameworks.”

(...) Dart is designed for a technical envelope that is particularly suited to client development, prioritizing both development (sub-second stateful hot reload) and high-quality production experiences across a wide variety of compilation targets (web, mobile, and desktop).

Dart also forms the foundation of Flutter. Dart provides the language and runtimes that power Flutter apps, but Dart also supports many core developer tasks like formatting, analyzing, and testing code.” [12]

The reasons why Dart has been chosen for this project besides it is Flutter’s programming language:

1. High performance: It’s compiled to native code which is highly optimized.
2. Cross-platform support: Dart can be compiled to mobile, web and desktop.
3. Strong typing: Errors can be caught at compile time rather than run time.
4. Library ecosystem: There are many Dart libraries with useful packages which are available for common tasks such as HTTP request, JSON parsing and much more.

3.1.1.3 Firebase

The Firebase mobile and web application development platform offers a cloud-based backend service for creating apps, handling user authentication, and storing and retrieving data in real-time. Google's Firebase is a service that provides a variety of services, such as Cloud Firestore, Cloud Functions, Authentication, Cloud Storage, and Real-time Database.

A NoSQL document database called Cloud Firestore enables real-time data synchronization between devices. When events occur in the app, cloud functions are utilized to launch backend processes. Using well-known providers like Google, Facebook, and Twitter, authentication ensures secure user authentication. Real-time Database is a database stored in the cloud that stores data in JSON format, and Cloud Storage offers cloud storage for your app. [13]

The advantages of using Firebase are numerous since it makes the process of creating apps faster by offering simple-to-use tools and services. Building real-time apps is great for Firebase because it is scalable, can handle enormous amounts of data, and offers real-time data synchronization. Furthermore, Firebase offers comprehensive documentation and a welcoming developer community, making it simple to understand and utilize.

The reasons why Firebase has been chosen for this project:

1. Firebase offers a complete suite of backend services that are easy to integrate into your app.
2. Firebase has a simple API that is easy to learn.

3. Firebase provides real-time data synchronization, which is essential for real-time applications.
4. Firebase offers user authentication, which makes it easy to secure your app and protect user data.
5. Firebase is scalable and can handle large amounts of data, which is important for future growth of your app.

To summarize, Firebase is an efficient backend platform that offers a variety of services for creating mobile and web applications. By offering simple, scalable, and dependable tools and services, Firebase makes the process of creating apps faster. For creating real-time applications that need user authentication and real-time data synchronization, Firebase is the ideal route. [14]

3.1.2 Approaches to software development and design

The approach to software development and design section goes in-depth on the frameworks and methodologies used to create the application. This section is focused on the software development model adopted, the use of Material Design, and the Bloc architecture implementation. The methods covered in this section were essential to the application's successful development and deployment, and their importance to the project will be carefully analyzed.

5.1.2.1 Software development model

The Spiral model is a software development life cycle model that was proposed by Boehm [15], and it combines elements of evolutionary, waterfall, and prototyping models. It is typically used in large, complex, and expensive projects where risk assessment is critical, and there is a budget constraint. The unique feature of the Spiral model is its ability to handle risks effectively by incorporating a risk analysis and management process. The model consists of a spiral-like structure with several loops, where each loop represents a software development process phase. The number of loops is subjective and depends on the project's requirements, and the project manager determines the steps required for product development. The model consists of four quadrants: finding alternative solutions and identifying objectives, determining and solving risks, upgrading the product to the upcoming version, and reviewing and planning for the next section. The model's pricing and

development progress can be determined based on the radius and angular attributes. The model is more workable compared to other models since it allows for a build-up model at every step of software development, which helps manage and cope with unknown risks that can emerge during the development process. Overall, the Spiral model provides support for risk handling and is one of the most important types of software development life cycle models. [15]

3.1.2.2 Design pattern: Business Logic Component

To create scalable and maintainable Flutter apps, developers frequently use the Business Logic Component (BLoC) architecture pattern. By introducing a new layer, the BLoC layer, it separates the display layer from the business logic layer and the data layer. A clear separation of concerns is provided by the BLoC layer, which serves as a bridge between the display layer, the business logic layer, and the data layer. This makes the application simpler to maintain and scale.

The BLoC library is an open-source library used in applications to implement the BLoC architecture. The Cubit class is one of the most important component of the BLoC library. An easy and effective method of managing state in applications is provided by Cubit, a lightweight implementation of the BLoC architecture. It functions by generating a stream of state updates available for the presentation layer to consume. The presentation layer rebuilds the required widgets when the state changes since the Cubit broadcasts a new state update to the stream. This enables a reactive programming technique where the presentation layer can react in real-time to state changes without the need for manual callbacks or state management. From straightforward value-based state management to complex asynchronous operations, Cubit is incredibly adaptable and can be used to implement a variety of business logic scenarios. For implementing the BLoC pattern in Flutter applications, Cubit offers a robust and user-friendly interface.

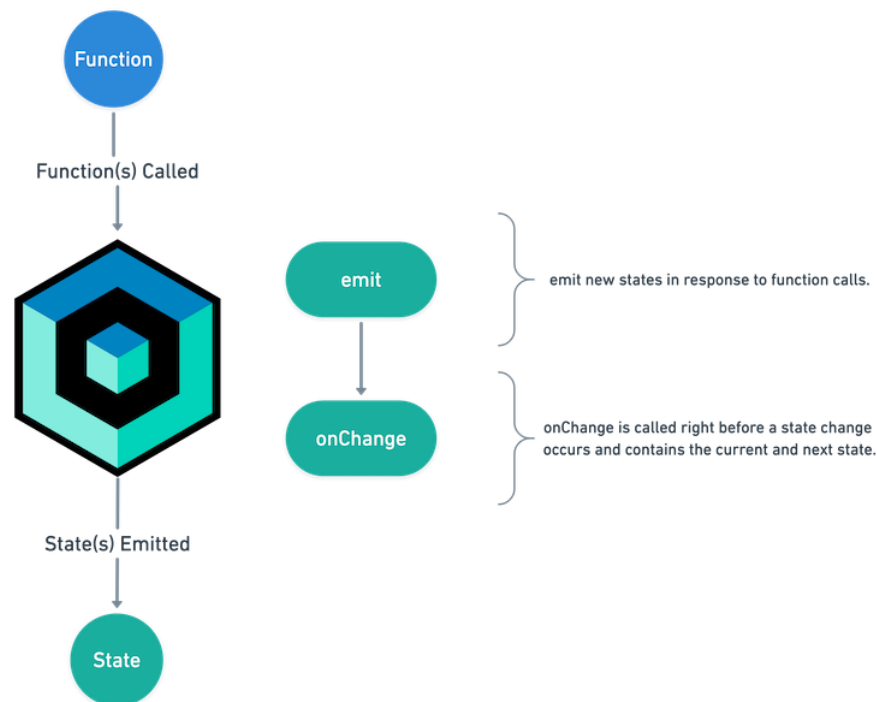


Figure 6 BLoC Pattern state [16]

Advantages of using the BLoC architecture:

1. Separation of concerns: The BLoC architecture separates the presentation layer from the business logic and data layer, making it easier to maintain and scale the application.
2. Testability: The BLoC architecture and the BLoC library provide a clear separation of concerns, making it easier to write unit tests for each component of the application.
3. Reusability: The BLoC architecture and the BLoC library allow for reusable components that can be used in multiple parts of the application.
4. Performance: The BLoC architecture and the BLoC library provide a reactive programming approach, which can improve the performance and user experience of the application.
5. Community support: The BLoC library has a large and active community of developers, which means that there are a wealth of resources, tutorials, and support available for developers who use the library.

The BLoC architecture and library are effective resources for creating scalable, maintainable, and high-performance Flutter applications. It is a great option for developers who wish to create high-quality applications due to the clear separation of concerns, testability, reusability, performance advantages, and community support. [16]

3.1.2.3 Material Design and accessibility

Material Design is a design language developed by Google that aims to provide a consistent look and feel across different platforms and devices. It includes a set of design principles, guidelines, and components that can help developers create intuitive and engaging user interfaces for their apps. [18]

Accessibility is a key component of Material Design. The term "accessibility" describes how something has been designed so that it can be used by someone with a disability. Accessibility in the context of app design refers to ensuring that all users, including those with impairments, can access and utilize the features and content of the app.

Google offers accessibility guidelines and components that developers may use to make sure that apps created with Material Design are accessible. Color contrast, typography, focus states, navigation, and screen readers are just a few of the accessibility elements that are covered in these guidelines. Along with these elements, Material Design offers a selection of the best practices for accessibility that developers can use. These proposed approaches include providing captions or transcripts for audio and video content, utilizing informative labels for form controls, and offering alternate language for images. [18]

Leveraging Flutter, Dart, and Firebase allowed for efficient development of the P-Game debate app. Overall, this development approach ensured a robust and user-centric platform for online debate.

3.1.3 P-Game specific features

Beyond the core cross-platform functionalities enabled by Flutter, Dart, and Firebase, the P-Game application incorporates specific features designed to enhance the online debate experience and promote critical thinking within a controlled environment.

Voice chat for mitigating bias in argument evaluation, P-Game employs voice chat as the primary communication tool during debates. This approach is grounded in research suggesting that voice-based interaction, compared to video conferencing, can lead to a reduction in bias during argument evaluation [24]. The rationale behind this lies in the removal of the visual element, which can introduce biases based on appearance. By focusing solely on the voice, participants concentrate on the content and structure of arguments, fostering a more objective evaluation process. Additionally, voice chat can create a more comfortable environment for some users who might experience self-consciousness on camera, potentially leading to increased participation and more open expression of ideas.

Finally, voice chat minimizes the influence of nonverbal cues like facial expressions or body language, which can sometimes be misinterpreted and lead to biased judgments.

Asynchronous debate participation to facilitate knowledge acquisition. The P-Game acknowledges the importance of flexibility in the learning process. Unlike traditional in-person debates with fixed schedules, P-Game allows for asynchronous participation. This means that users can:

- Participate in debates at a time that best suits their schedule, regardless of time zone or personal commitments. This flexibility caters to individuals with diverse schedules and promotes inclusivity.
- Asynchronous participation allows users to dedicate ample time to researching their assigned roles and prepare strong arguments without the pressure of real-time debate. This approach fosters deeper knowledge acquisition and encourages the development of well-structured, well-supported arguments.

Location independence fostering global debate participation P-Game leverages the power of online learning by offering complete location independence. With an internet connection, users can:

- Participate in debates with fellow debaters from around the world, creating a diverse and enriching learning experience. This exposure to different perspectives broadens participants' understanding of the debate topic and allows them to develop a more nuanced approach to argumentation.
- Participate in debates while traveling, commuting, or from the comfort of their own home. This flexibility allows users to seamlessly integrate debate participation into their daily routines, maximizing accessibility and fostering a wider range of participation.

These unique features, combined with the pedagogical value of debate games, position P-Game as a valuable tool for promoting critical thinking, communication skills, and knowledge acquisition in a flexible, unbiased, and accessible online environment.

3.2 Testing methodology

Building on the success of the P-Game study, this project will also utilize the same pre- and post-game surveys [4] employed in their research. These surveys, designed to assess knowledge gain and engagement, proved valuable in evaluating the effectiveness of the P-Game methodology. By adopting the same surveys, we can establish consistency and

potentially create a basis for comparison between our findings of the online method versus the offline one. This approach allows us to leverage their established tools and contribute to a broader understanding of the effectiveness of this learning methodology.

In addition to the pre- and post-game surveys used in the P-Game study, this research will also incorporate the System Usability Scale (SUS) [6]. This ten-item questionnaire offers a valuable tool for understanding user experience in online environments, which is particularly relevant given the P-Game's online format. The SUS will provide us with feedback on the usability of the P-Game itself, allowing us to identify areas for improvement and ensure a smooth and positive experience for future participants. By combining the P-Game's established surveys with the SUS, we gain a comprehensive picture of both knowledge gain and user experience, ultimately enriching our understanding of the P-Game's effectiveness in this online setting.

3.3 The survey

While the P-Game study's pre- and post-game surveys provide valuable insights through open-ended questions, our evaluation will take a more comprehensive approach. We'll utilize the SUS, a standardized questionnaire, to gather quantitative data on user experience. This numeric data allows for easy comparison and statistical analysis, providing a clear picture of overall usability. However, to gain a deeper understanding of participant reactions, we'll also incorporate the P-Game's open-ended questions. These qualitative elements allow participants to express their thoughts and experiences in their own words, potentially revealing aspects of the P-Game that quantitative data might miss. By combining these methods, we aim to capture a well-rounded picture of user experience, encompassing both objective usability metrics and subjective participant perspectives.

3.4 Evaluation

To assess the effectiveness of the online adaptation, we will employ a two-pronged approach. First, we will utilize the pre- and post-game surveys (previously discussed in Section 2.3.2) to evaluate changes in participants' knowledge and experience through a paired-samples t-test (introduced in Section 2.3.3). This will allow us to statistically determine if the online version significantly impacts learning outcomes compared to the traditional in-person format. Additionally, we will gather supplementary feedback through the System Usability Scale

(SUS), a ten-item questionnaire discussed in Section 2.3.4. While the SUS scores won't be directly compared to the survey results, they will provide valuable insights into the overall user experience of the online game, helping us identify areas for further improvement.

4. Development

4.1 Architectural design and data flow

By adopting clean architecture for user management and data storage, you've achieved several benefits. Figure 7 represents the call flow in the application, it's exhibiting a clear delineation among the user interface, logic, and data layers. Interaction begins at the frontend with a button press, triggering a Cubit responsible for state management and data invocation. The data access layer is methodically partitioned into three principal components: the service component, an interface, and the underlying repository. This architectural stratification not only facilitates adaptability to backend modifications but also enhances maintainability.

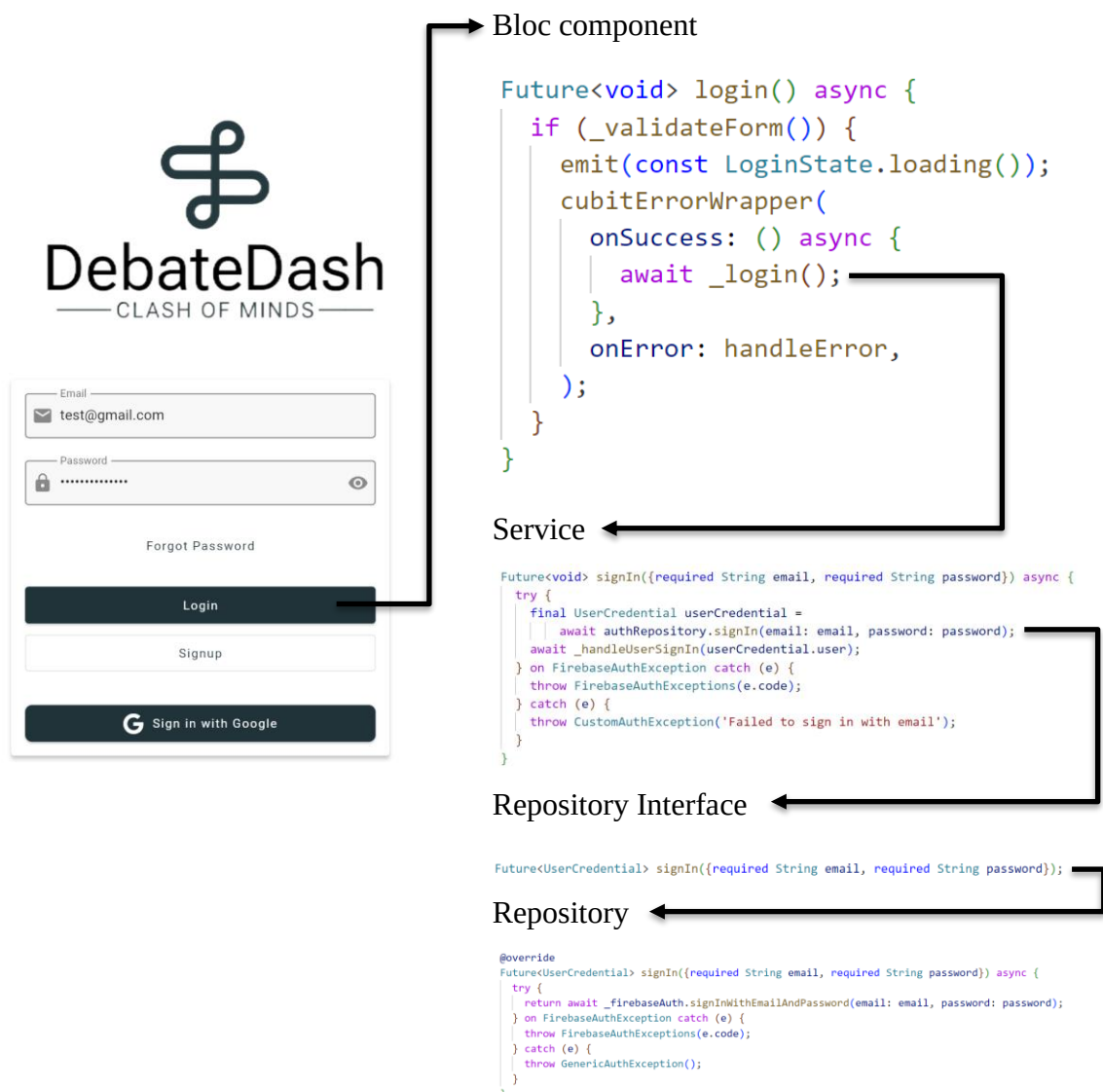


Figure 7 Call flow

4.2 Authentication and data storing

Firebase Authentication offers a comprehensive suite of features to manage user login and registration. This section outlines the integration process within your Flutter application.

4.2.1 Adding firebase to the user registration and login

In the implementation of the authentication system for the application, Firebase Authentication is employed as the core technology. Utilizing the FirebaseAuth class from the firebase_auth package, the AuthRepository class provides comprehensive functionalities such as sign-up, sign-in, sign-out, and password resets, alongside integration with Google Sign-In for an alternative authentication method. The repository pattern is adhered to, encapsulating all authentication-related operations within the AuthRepository class, which implements the IAuthRepository interface. This setup ensures a clear separation of concerns and enhances the maintainability of the code. Exception handling is robust, with specific exceptions thrown for different Firebase and authentication-related errors, ensuring that the application can gracefully handle errors and provide relevant feedback to users.

4.2.2 Building a Scalable User Database with Cloud Firestore

As discussed in chapter 3.1.1 Firebase Authentication and Cloud Firestore is a great tool for building applications, in this section aims to show it integrated in the game.

The UserRepository class uses Firestore to manage user profiles within the application effectively. For instance, user profiles, including display names, email addresses, match statistics, profile pictures, and Firebase Cloud Messaging (FCM) tokens, are stored and retrieved from Firestore. This is illustrated in the repository's methods such as createUserProfile, getUserProfile, updateUserProfile, and deleteUserProfile. These functions utilize Firestore's robust capabilities to perform CRUD operations on the users collection.

For example, in the createUserProfile method:

```
final userDoc = _firestore.collection(usersCollection).doc(userProfile.id);  
await userDoc.set(userProfile.toJson());
```

This snippet demonstrates adding a new user profile to Firestore, where userProfile.toJson() efficiently converts the UserProfile class instance into a JSON format suitable for Firestore storage, leveraging the freezed package. This package aids in data serialization and provides immutable data structures, making the code more robust and type-safe.

Furthermore, the integration of Firebase with other Firebase services like Firebase Authentication and Firebase Cloud Messaging (FCM) enhances the overall functionality. For instance, storing FCM tokens in user profiles allows the application to manage push notifications effectively:

```
await FirebaseFirestore.instance  
.collection('users')  
.doc(userId)  
.update({'fcmToken': fcmToken});
```

This method updates the FCM token in the user's document, ensuring the app can send notifications to the right device.

Using Firestore in conjunction with Firebase Authentication ensures that user data remains consistent and secure, as Firebase handles all user authentication before allowing access to their Firestore database. This setup not only provides a seamless user experience but also simplifies the backend infrastructure, reducing development time and increasing reliability.

4.3 Enabling Real-time Notifications with Firebase Cloud Messaging (FCM)

The FCM token for each user, obtained during registration or app usage, is stored within the user's document.

```

/**
 * Cloud Function to notify chat room status updates.
 */
exports.notifyChatRoomStatus = functions.region('europe-west1').firestore
  .document('chatrooms/{chatroomId}')
  .onUpdate(async (change, context) => {
    console.log('Function triggered for document:', context);

    const previousData = change.before.data();
    const newData = change.after.data();

    // Check for game state changes
    if (newData.status !== previousData.status) {
      const notificationMessage = getNotificationMessageForStatus(newData.status);
      // Send notification to all members
      await sendNotificationToAllMembers(newData.memberIds, notificationMessage);
    }

    // Notify current user to record speech
    if (newData.currentUserIndex !== previousData.currentUserIndex) {
      const currentUserId = newData.memberIds[newData.currentUserIndex];
      await sendNotificationToUser(currentUserId, 'It\'s your turn to speak!');
    }
  });
}

/**
 * Retrieves the notification message for a given status.
 * @param {string} status - The status of the chat room.
 * @return {string} The notification message.
 */
function getNotificationMessageForStatus(status) {
  switch (status) {
    case 'started':
      return 'The game has started!';
    case 'finished':
      return 'The game has finished! and it is time to rate each other.';
    default:
      return '';
  }
}

```

Figure 8 Message trigger

This token allows targeted notification delivery to individual users. The code snippet on Figure 8 features a Cloud function that is triggered by updates to a document in the Firestore collection chatrooms. The function handles different types of notifications based on the room's status and the current user's turn to speak.



Figure 9 access user permission

To ensure a smooth user experience and comply with platform guidelines, it's important to request notification permissions from users proactively. On Figure 9 a specific permission handling can be seen both in code (left) and the visual representation of the UI (right).

Real-time Voice Chat Integration



Figure 10

If the notifyChatRoomStatus function is triggered the function automatically triggers the notification for the specific platform can be seen on figure 10.

4.4 Debate Rating System

In our application, we have implemented a user-rating system to foster a community-driven environment where players can rate each other. This feature is encapsulated within the RatingDialog widget (Figure 11). It provides a straightforward and interactive platform for users to submit ratings for each other based on their gameplay experience. This dialog utilizes a list of UserProfile objects to display players and allows users to rank each other by dragging and arranging player profiles in order of preference. Upon submission, these rankings are

processed to update user profiles with new ratings, which are then stored securely in Firebase Cloud Firestore.

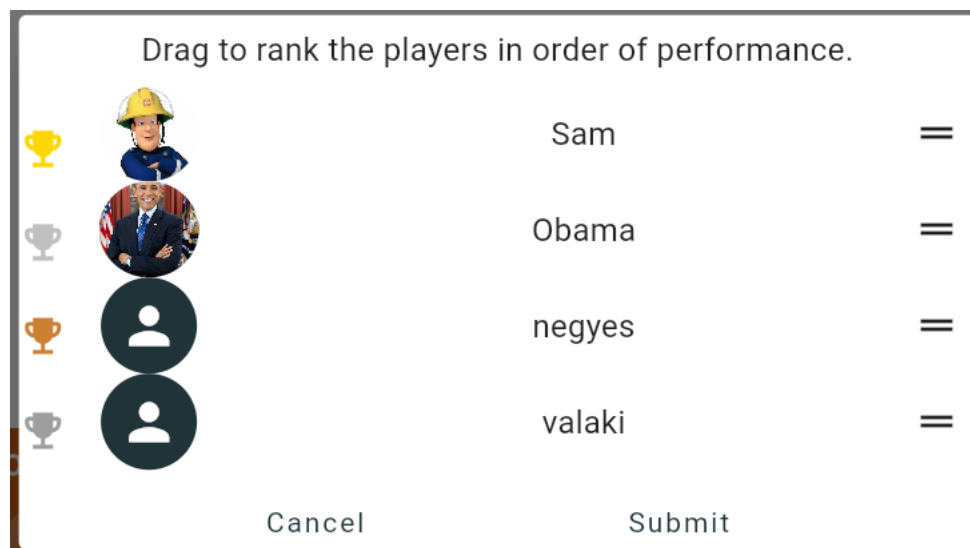
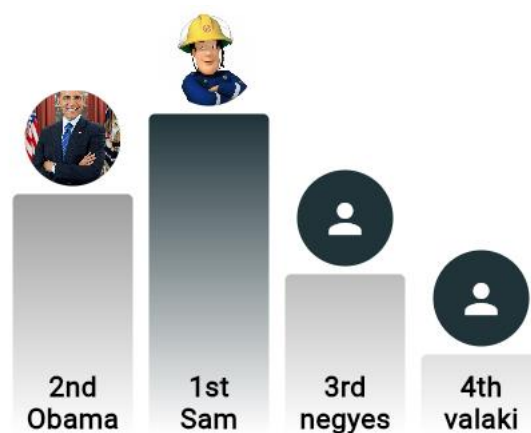


Figure 11 RatingDialog

The system not only promotes fair play and recognition among players but also enhances user engagement by integrating a social element into the game. By allowing players to rate each other, we establish a sense of community and accountability, encouraging players to interact more positively and constructively during games.

To visually represent the outcomes of these interactions, we also incorporate a PodiumWidget (Figure 12). This widget graphically displays the top-rated players in a podium format, symbolizing their ranking and achievements in the game. The use of vibrant colors and dynamic heights for each podium position creates an engaging and rewarding experience, further motivating players to participate and excel.



You placed in the top 1!

Figure 12 Podium widget

These features exemplify how our application leverages Flutter's powerful UI capabilities combined with Firebase's robust backend services to create a comprehensive and interactive user experience.

5. Results

In this section, we delve into the limitations of the system usability results obtained from our recent testing phase. Our analysis will focus on the inherent constraints, user experience feedback and system performance assessments between the digital application and its traditional counterpart. By examining these differences, we aim to understand the implications for overall usability and identify potential areas for improvement in future iterations of the system.

5.1 Limitations

The testing phase of our application was notably constrained by both time and the number of participants involved. Limited to a two-week period, our ability to conduct a comprehensive range of tests was significantly restricted. Unlike the face-to-face (F2F) game, which engaged a larger group of testers, we managed to recruit only 25 testers for this digital version. This smaller pool of participants limited our insights into user experience and system performance under diverse conditions. These constraints prevented us from fully exploring the application's behavior across a broader spectrum of use cases and user interactions, which could have unveiled more nuanced insights and potential improvements. Moving forward, extending the testing period and increasing participant diversity will be crucial to ensuring a more robust and user-friendly application.

5.2 SUS result

The System Usability Scale (SUS) provides a reliable tool to evaluate the usability of various systems. It involves a straightforward calculation method outlined below:

“To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1,3,5,7, and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU.” [6]

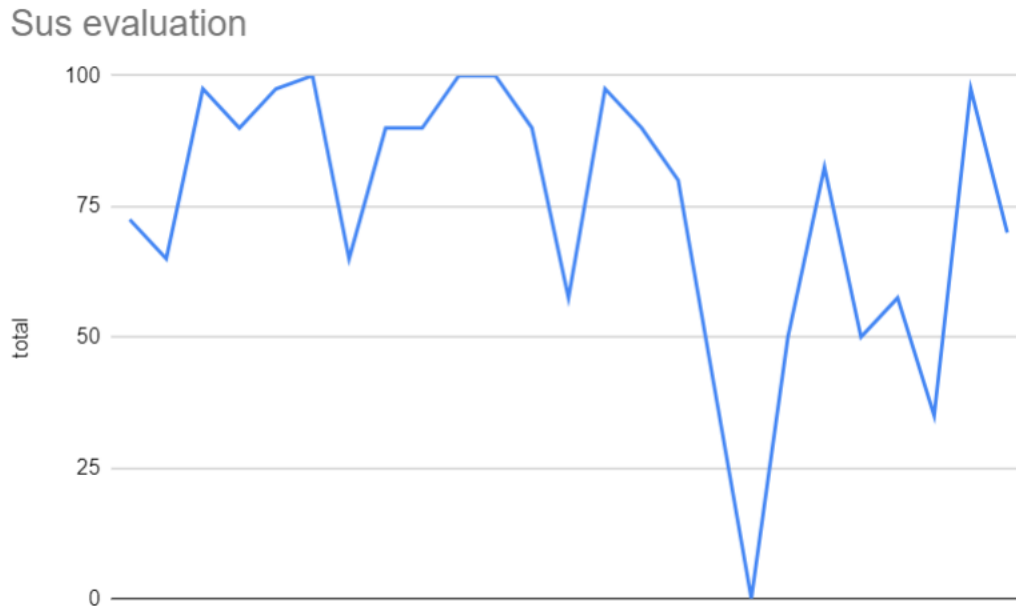


Figure 13 SUS evaluations

In our analysis, the average SUS score was determined to be 74.6. According to standard SUS evaluation guidelines, a score above 68 is considered acceptable, whereas scores exceeding 80.3 are deemed excellent [25]. An examination of Figure 13 reveals three notably low scores, which upon further investigation were linked to a significant bug that has since been resolved. Excluding these anomalies, the recalculated SUS score slightly exceeds 81, reflecting a 'great' usability level. This adjustment underscores the importance of continuous system monitoring and bug fixing in maintaining the integrity of usability assessments.

5.3 Direct comparison

This comparison based on the survey mentioned in 2.4.2 sub-chapter, and seen on Figure 4.2 and 4.2.

5.3.1

The face-to-face (F2F) version of the game has achieved international reach, being played in over 14 countries [4]. My survey, however, focused on a smaller scale, capturing responses from players in four countries. The distribution of survey participants is as follows: 22 players from Hungary, representing 88% of the sample, along with one player each from Austria, the Netherlands, and Germany. This data indicates that the game has successfully penetrated multiple countries simultaneously.

Regarding participant demographics in the face-to-face game, out of the 261 participants, a significant majority, 188 students (72%), identified as science majors. The remaining 73

participants (28%) reported majoring in the social sciences. In contrast, my own testing presented a more balanced participation. As seen in Figure 11, 46.4% of respondents were social science students, with the remainder from science disciplines. This indicates a more evenly distributed interest across academic fields in my study compared to the face-to-face version.

Do you consider yourself a science or social science student? Természettudományi vagy társadalomtudományi hallgatónak tartod magad?

28 válasz

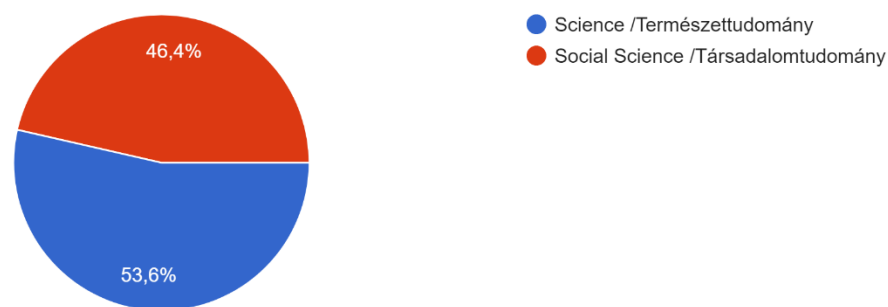


Figure 14 science or social science students

5.3.2 Educational and Demographic

In the face-to-face (F2F) game, the educational background of participants was predominantly undergraduate and graduate students, with 63% being BSc students and 24% MSc students. Additionally, 12% of participants were engaged in PhD studies, and 3% had already been awarded a PhD. The gender distribution was relatively balanced, with 43% male and 57% female participants, achieving a noteworthy equilibrium in participation [4].

In contrast, the online testing method showed a different educational spread: 92% of participants were BSc students, with only 8% being MSc students. The gender balance was also noteworthy in the online method, with 56% male, 40% female, and 4% preferring not to disclose their gender. This indicates that while the educational level skewed more towards undergraduate students, gender diversity remained consistent across both formats.

5.3.3 Impact on Knowledge Acquisition

Participants in the face-to-face game reported significant educational benefits, particularly in specialized scientific domains. According to data collected, 66.3% of participants noted an improvement in their understanding of phosphorous science, while 64.0% observed enhanced

skills in negotiation science/practice. Despite these improvements, 30% of participants remained neutral, indicating no change in their knowledge levels in these areas post-game [4].

In comparison, my survey results from the online method showed similar trends in knowledge enhancement: 68% of respondents experienced a boost in phosphorous science knowledge and 60% in negotiation skills. However, a slightly lower percentage of respondents, 24% for phosphorous science and 28% for negotiation science, reported neutral impacts, suggesting a modest difference in self-assessed educational impact between the two methods.

6. Conclusion

In conclusion, the development of the online P-Game has proven to be an adequate and successful extension of its face-to-face counterpart. Through meticulous testing and implementation, this digital version has established its right to exist by demonstrating significant educational benefits and increased accessibility. The online format has notably expanded participation, enabling individuals from diverse geographical locations to engage seamlessly. This increased accessibility has not only broadened the reach of the game but has also inclusively enhanced the educational experience for participants who may have previously been unable to attend physical sessions. Therefore, the P-Game online platform stands as a testament to how digital transformation can effectively bridge educational gaps and foster a more inclusive learning environment.

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