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JellyfishGO!: Exploring Citizen Science Users' Engagement with Gamification Strategies

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Abstract

This thesis explores the design, development, and evaluation of JellyfishGO!, a mobile augmented reality (AR) application aimed at enhancing citizen engagement in jellyfish swarm monitoring through gamification. Inspired by PokémonGO!, JellyfishGO! leverages game mechanics to motivate public participation in scientific data collection as part of the EU-funded Iliad consortium's efforts to forecast jellyfish swarms. The research investigates which gamification strategies most effectively promote player engagement, retention, and scientific contribution, addressing core challenges in citizen science game design.

A systematic literature review was conducted to identify trends and gaps in gamification within citizen science projects. The JellyfishGO! app was then enhanced with selected game elements—such as points, leaderboards, missions, and team-based dynamics—based on insights from the literature. A design science research methodology guided the iterative development and experimental evaluation of the app. The game was tested over a one-week period with voluntary participants, whose engagement was analyzed through in-game behavior and post-study questionnaires, including the System Usability Scale (SUS), Gaming Motivation Scale (GAMS), Player Experience of Need Satisfaction (PENS), and a custom Element Impact Questionnaire (EIQ).

The results showed that intrinsic motivations (such as enjoyment and personal value) were the primary drivers of participation, with competence and autonomy being the most fulfilled psychological needs. Among game elements, individual leaderboards and missions had the greatest motivational impact. The study concludes with design recommendations for future citizen science games, emphasizing the need to balance intrinsic and extrinsic motivators while aligning with citizen science principles to foster long-term engagement and meaningful scientific contributions.

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To my family, and to my friends, in the workplace, online and my cherished group "$ARDA$", your constant support and belief in me always kept me going and gave me the strength to see this to the end. I would like to specially thank my mother and my brother for always being there for me and providing me with their unwavering and unconditional love and support, I am deeply grateful. To my father, who sadly could not get to see me complete my dissertation and this chapter of my life, I dedicate it to him. And although from afar, I thank Tamires for her faith in me, endless prayers of my success, and staying with me for this whole journey.

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Abbreviations

PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
IEEE	Institute of Electrical and Electronics Engineers
ACM	Association for Computing Machinery
WOS	Web Of Science

Chapter 1

Introduction

1.1 Context

The Iliad (Integrated DigitaL Framework For Comprehensive Maritime Data And Information Services) consortium, funded in part by the EU, aims at establishing an interoperable, data-intensive, and cost-effective Digital Twins of the Ocean [12]. These virtual representations integrate earth observing, modeling and digital infrastructures to provide predictions of future developments "at sea". It acts on several domains regarding the ocean, including but not limited to: Oil Spills, Harbour Safety, Aquaculture, Ocean Energy Potential, and Jellyfish Swarm Forecasting.

Jellyfish swarms are a significant concern, as they not only deter ocean enthusiasts but also pose a real threat to those who venture into the sea during these events. The repercussions are not limited to personal safety; they have substantial economic implications too. Coastal tourism and operations suffer billion-euro damages due to these swarms; while seawater intake systems of ships, power, and desalination plants often clog up, leading to operational losses, intensive maintenance, and repairs that cost millions.

Iliad's Jellyfish Swarm Forecast pilot project addresses this concern, led by partner organization the University of Haifa, with the creation of a jellyfish forecast and online map, using data contributed by citizens [14]. The intention is not to eliminate these creatures, but to provide timely alerts about their presence, ensuring the ocean remains a safe and accessible space for all, while also mitigating their impact on oceanic economies. This early warning system will be a beacon for municipalities, national bodies, the general public, and various industries, empowering them to anticipate and respond proactively to imminent swarm arrivals, while being grounded in citizen science [13].

Citizen science is a flexible concept which can be adapted and applied within diverse situations and disciplines [10]. The European Citizen Science Association (ECSA) has set out to define ten core principles on which citizen science rests, to ensure the following of good practices [10]. These principles emphasize the meaningful involvement of citizens in scientific endeavors that generate new knowledge or understanding, with citizens participating as contributors, collaborators, or even leaders. These projects must have genuine scientific outcomes, such as addressing

research questions or influencing policy. Both professional and citizen scientists benefit, gaining opportunities for learning, enjoyment, and societal impact. Citizen scientists can engage in various stages of the scientific process, and they receive feedback on how their contributions are used. The approach emphasizes public engagement, data sharing, and open access, while addressing ethical and legal considerations. Evaluation of projects is crucial for ensuring scientific rigor, data quality, and societal benefits.

By leveraging the collected wisdom from its citizen contributors, the Jellyfish Swarm Forecast pilot project has already managed remarkable progress and achievements, such as successfully forecasting a jellyfish swarm that impacted a power plant [14], identifying patterns leading to an anomalous jellyfish-free summer, and reporting species of jellyfish that are new to science and documentation of extreme sizes for existing species.

The Iliad consortium wants to expand the coverage of this pilot project to the Southern European seas, and to this end has created a network of 13 jellyfish observation initiatives, all based on citizen science, to monitor these seas.

1.2 Motivation

JellyfishGO! is one of the jellyfish observation initiatives launched by the Jellyfish Swarm Forecast pilot project to extend their forecasting and tracking to the Southern European seas. It is grounded in citizen science, in the same vein as its pilot project and the other launched initiatives as part of the Southern European seas expansion.

More specifically, it is an Augmented Reality (AR) mobile application inspired in the popular game PokémonGO! [26], borrowing its core concepts of capture and collection of digital lifeforms, which in the case of JellyfishGO! are digital models of actual species of jellyfish.

JellyfishGO! thus aims to tackle jellyfish swarm forecasting through gamification, and to employ gamification strategies that can both captivate citizens to contribute with observations, as well as educate the general population regarding these animal species and ocean preservation. However, at the current moment, the mobile application is in a very early state, with more features and gamification strategies required to fulfill the key principles of citizen science and increase citizen engagement and data collection.

1.3 Problem

Citizen science games (CSGs) are a valuable means for motivating citizen science participation. Unfortunately, many CSGs still suffer from the recruitment and retention issues of traditional citizen science projects, despite much prior literature on what motivates CSG players [22]. Another factor for motivating citizen science participation is the successful inclusion of its core principles, such as clarity in contribution feedback. Citizen scientists should be made aware that their contributions are making an impact in the world surrounding them, and to be acknowledged in a significant capacity of these same contributions.

The low player recruitment and retention rates, combined with the insufficient application of the key principles of citizen science, are reasons that lead to a limited number of observations and collected data, which can then lead to the failure of projects.

It is a complex challenge to design and implement gamification strategies that can simultaneously achieve player engagement while satisfying the principles of citizen science. Yet these strategies are essential in order to ensure significant and long lasting citizen contributions, and the success of this kind of citizen science based projects. The development of gamification strategies that strike the balance between a high level of player engagement and fulfillment of citizen science principles form the core of the problem addressed in this thesis.

1.4 Research Questions

Following the problem outlined in the previous section, it is crucial to identify the gamification strategies that align with the genre of game JellyfishGO! fits in. Several of these strategies exist, and not all of them will be implemented in JellyfishGO! due to time and complexity constraints. These goals can be translated into the following research questions:

RQ1: Which gamification strategies are the most impactful in terms of player engagement and retention?

RQ2: What is the effect of the introduction of gamification strategies on player contribution in a citizen science project?

1.5 Methodology

Throughout this dissertation, the following methodology will be taken:

1. **Literature Review:** A literature review is performed to study and gather knowledge regarding the research done on the relevant topics, namely gamification in citizen science.

2. **State of the Art:** After reviewing the literature, a state of the art is outlined, based on the review. This will help form a foundation of current knowledge and methods from where the next steps will base themselves on.

3. **Development of JellyfishGO!:** Gamification strategies are going to be implemented into the game of JellyfishGO!, their selection being based on the state of the art and literature review.

4. **Experimental Study:** A study is carried out with the newly developed version of JellyfishGO!, with data collected to then analyze and provide answers to the research questions.

1.6 Document Structure

Besides the introduction, this dissertation contains 6 more chapters. In chapter 2, a systematic literature review is performed to identify trend and gaps in the research. In chapter 3, there is a review of the state-of-the-art. In chapter 4, the solution is presented and discussed. In chapter 5, the experimental protocol to be carried out is explained. In chapter 6, the results of the experiment are shown and analyzed. In chapter 7, the conclusions about the project are outlined.

Chapter 2

Literature Review

2.1 Introduction

This chapter focuses on reviewing the literature regarding gamification in citizen science related projects. The main goal is to identify and analyze how gamification was implemented, and what impact the gamification strategies employed had on player engagement, retention and contribution, the overall quality of the contributions, and the general success of the project.

2.2 Theoretical Framework

The theoretical framework of this literature review centers on gamification of citizen science projects. The concepts revolve around the implementation of specific gamification strategies that influence player engagement, retention and contribution, and affect the overall success of the citizen science projects they were implemented in.

2.3 Method

The research was conducted using a systematic review process, structured to identify and analyze relevant studies. The methodology followed the PRISMA protocol to ensure transparency, reproducibility, and rigor in the identification, screening, and inclusion of studies.

The search strategy involved queries that were broad enough to capture as much potential information as possible, while still remaining within the appropriate scope.

2.3.1 Databases and Queries Used

This review made use of established academic databases, such as IEEE Xplore, Web of Science (WoS), ACM Digital Library and Science Direct, due to their extensive and wide collection of studies. The query string used to collect work records is shown in table 2.1, tailored to encompass relevant literature.

Table 2.1: Search Strategy for Publications

Database	**Query String**	**Period**	**Document**	**Language**	**Search Goals**
WoS, Science Direct, IEEE Xplorer, ACM	"citizen science" AND ("game" OR "program") AND "gamification"	2014-2024	Article, Conference Paper, Proceeding Paper, or Book	English	• Citizen science projects that implemented gamification strategies • Discussion on the impact of gamification strategies in player engagement, retention and contribution

2.3.2 Query Refinement Process

The iterative refinement of the queries, as summarized in Table 2.2, was essential to improve the precision and relevance of the retrieved articles. Each query was adjusted to address specific challenges identified during the systematic review process.

Initially, the intent was to get a general overview of the amount of research and publications on the key concepts of this work. Thus, the first query string (QS1) includes only the main keywords "citizen science" and "gamification". Although this initial query string succeeded in retrieving a large amount of records, unfortunately many were irrelevant or tangential to this study. For example, QS1 captured articles that relate to gamification, but not in the context of a citizen science project.

Therefore, QS2 was a refinement of QS1, with the objective of narrowing down the search results by specifying the characteristics of the citizen science project inherent to this study, and thus the terms "game" and "program" were incorporated into the query string. The term "program" is also included in this new query string since in the records retrieved with the first query string there were publications which used this term instead of "project" to describe a citizen science project. This new query string returned fewer results than the previous one, showing that the added specificity helped reduce the scope of the search.

This iterative refinement process, as illustrated in Table 2.2, highlights the importance of carefully designing search queries to balance the breadth and precision of results. These adjustments ensured that the final set of selected records closely aligned with the study's objectives.

Table 2.2: Records retrieved per query string

WoS, Science Direct, ACM, IEEE Xplorer		
Query ID	**Query String**	**Records retrieved**
QS1	"citizen science" AND "gamification"	272
QS2	"citizen science" AND ("game" OR "program") AND "gamification"	227

2.3.3 Search Process

The search process was similar across all the databases used, with minimal changes according to the specific way the search and filtering of results is done on each database's interface (i.e.

ScienceDirect and WoS have check-boxes for each of the years, whereas IEEE Xplore has a year range interval).

2.3.4 Inclusion Criteria

The inclusion criteria were established to ensure the selection of studies that are directly relevant, recent, and of high quality, meeting the specific needs of this research. Each criterion plays a critical role in filtering the most suitable literature:

- **Direct relevance to the study's objective**: Ensuring studies align with the research objectives is essential to avoid unrelated or tangential material, focusing only on literature that contributes directly to the understanding and discussion of gamification in citizen science projects and their impact on player engagement and retention.
- **Publications from 2014 to 2024**: Restricting the publication period to a recent but broad year range, specifically over the last decade, ensures that the research gathers several discussions on the topic of this study over time, which allows for a chronological analysis of them. Initially the range was narrower, only including the last five years, yet this yielded a very small number of records. This was another reason the gap was extended to the last decade.
- **Full-text access**: Full access to the documents is vital to gain a comprehensive understanding of each study's methodology, results, and implications. Abstracts alone often lack the depth required for critical evaluation.
- **Written in English**: Selecting studies in English broadens the scope to include a wider range of global research, as English is commonly used in scientific literature, thus enhancing the diversity and applicability of insights.
- **Published in relevant areas**: Verifying that the studies are published in the areas of discussion of this research is another guarantee that the studies are in accordance to the needs of the research. Specifically, to verify if they're published in the area of "Citizen Science" and "Games".
- **Inclusion of various, peer-reviewed document types (Articles, Conference Papers, or Books)**: Including different types of documents enriches the review by incorporating perspectives from foundational research, the latest findings, and peer-reviewed studies, offering a well-rounded understanding of the field.

2.3.5 Exclusion Criteria

The exclusion criteria were carefully designed to remove studies that do not meet the quality or relevance standards required for this research. Each criterion ensures that only meaningful and valuable studies are retained:

- **Lack of abstract or keywords**: Studies without abstracts or keywords are excluded, as these elements provide essential information for quickly assessing relevance. Without them, determining the focus and scope of a paper becomes difficult, especially in systematic reviews.
- **Irrelevant title / abstract**: Titles serve as the first indicator of a study's focus. And even if titles seem relevant, abstracts provide a clearer insight into a study's content. Excluding studies with irrelevant titles and abstracts helps streamline the selection process, allowing a more efficient focus on directly relevant literature.
- **Not written in English**: Studies not written in English restrict the understanding and applicability of insights they may have, as English is the common language used in scientific literature.
- **No full-text access**: Studies without full-text availability are excluded, as partial information hinders an in-depth analysis of methodologies, findings, and limitations, which are essential for a comprehensive literature review.
- **Lack of substantial discussion**: Papers that do not include insightful discussions regarding the implementation of gamification strategies in citizen science projects and their impact on player engagement and retention are excluded to maintain a focus on studies that add substantial value to the research.
- **Not summaries of workshops, seminars, lectures, or tutorials**: These types of documents are excluded because they often lack rigorous research methodologies and empirical evidence. Instead, they tend to summarize knowledge without the detailed analysis or validation needed for a thorough academic review.

2.3.6 Identification

As shown below in the table 2.3, a total of 499 initial records were retrieved from these databases. After applying the inclusion and exclusion criteria, 26 articles were identified as relevant for further analysis, representing 5.2% of the total records. The remaining 473 records were excluded, accounting for 94.8% of the total results, as represented in the image 2.1 below.

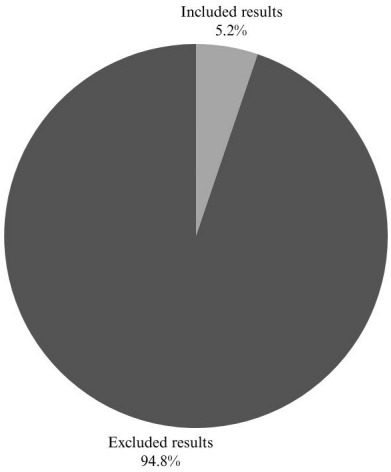


Figure 2.1: Included and excluded results.

As for comparison between databases, ACM yielded the most results with a total of 242, followed by Science Direct with 154 results. These two databases were also the ones with the most amount of results excluded, in the same order. Web of Science and IEEE Xplore produced significantly less results than the other two databases, 68 and 35 respectively.

In terms of contribution of relevant results, ACM contributed with the most at 14, followed by Web of Science and Science Direct at 5 each, and IEEE Xplore with the least contributed at only 2.

As seen in the table 2.3, the inclusion and exclusion process was critical in ensuring that only the most methodologically sound and contextually relevant studies were retained for the review. This highlights the importance of systematic filtering when conducting a robust literature review.

Table 2.3: Results of the Systematic Review by Database

Database	**Initial records**	**Relevant records**	**Excluded records**
Web of Science	68	5	63
Science Direct	154	5	149
ACM	242	14	228
IEEE Xplore	35	2	33
No. Total Results	**499**	**26**	**473**
%	**100%**	**5%**	**95%**

To provide a clear and structured overview of the systematic review process, the PRISMA flow diagram (Figure 2.2) is shown below. This diagram visually represents the identification, screening, eligibility, and inclusion phases of the study selection, showing the number of records processed at each stage and the reasons for exclusion.

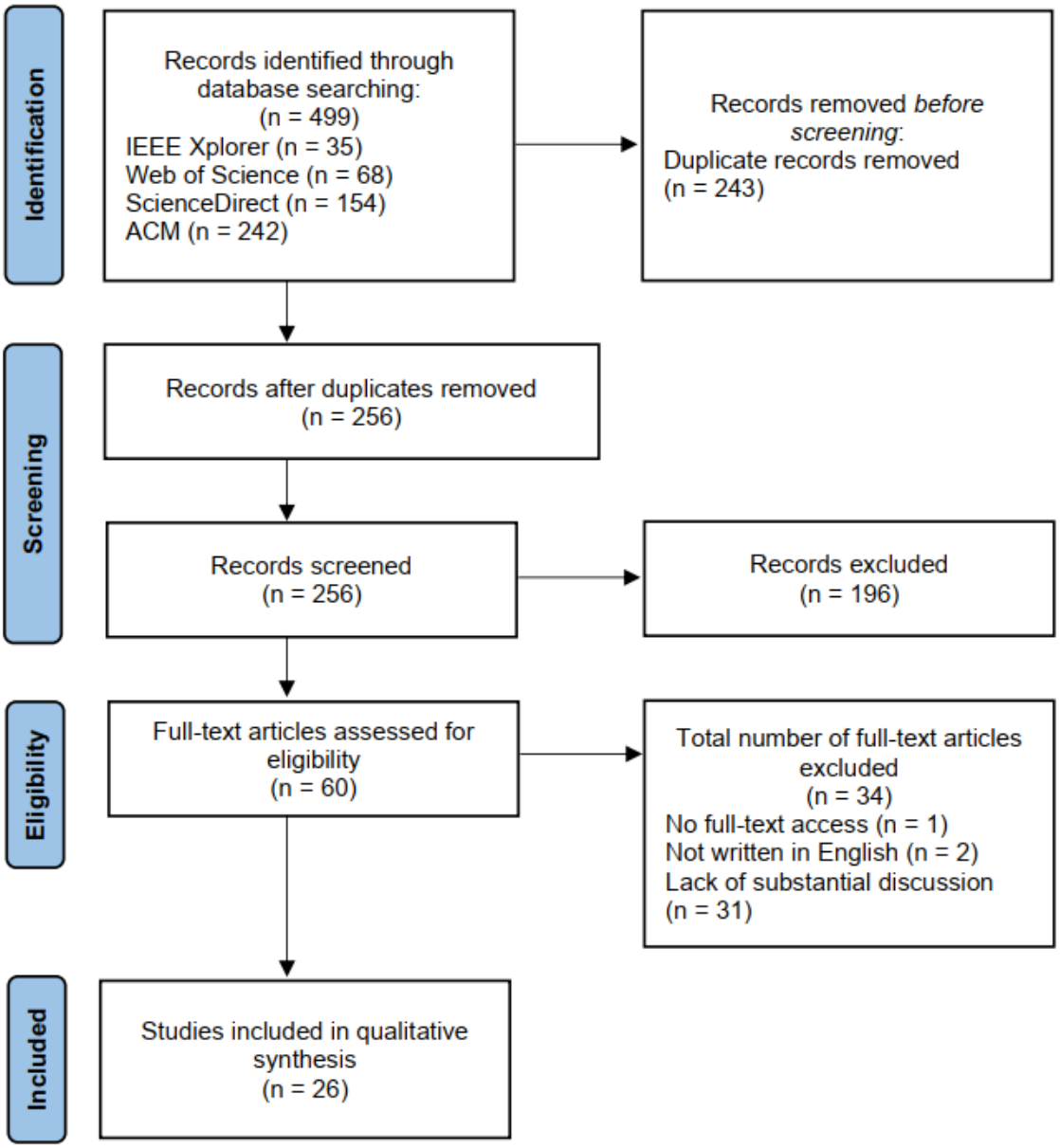


Figure 2.2: PRISMA Flow Diagram.

The exclusion criteria applied during the systematic review process are detailed in Table 2.4, which summarizes the total number of studies excluded based on each of the exclusion criteria.

The most frequent reason for exclusion was irrelevant titles and abstracts, accounting for 196 articles. This showcases the importance of the title and abstracts as early indicators of relevance. Similarly, 31 articles were excluded due to lack of substantial discussion on relevant topics such as citizen science and gamification strategies.

Additionally, 1 record was excluded due its full-text being inaccessible, and two other records were excluded as they were not written in English, which was a necessary inclusion criterion to ensure consistency in analysis.

This rigorous exclusion process ensured that only highly relevant studies remained for a detailed review, allowing the focus to remain on gamification in citizen science projects.

Table 2.4: Records Excluded per Criterion

Exclusion Criteria	**Records Excluded**
No abstract/keywords	0
Irrelevant title/abstract	196
No full-text access	1
Lack of substantial discussion	31
Other document types outside the inclusion criteria	0
Not written in English	2

The histogram below compares the sources of publication of the included results, whether they were part of a conference or published in a journal. The majority of the results come from conferences, with 16 of the results being proceedings, and the remaining 10 constitute journal publications.

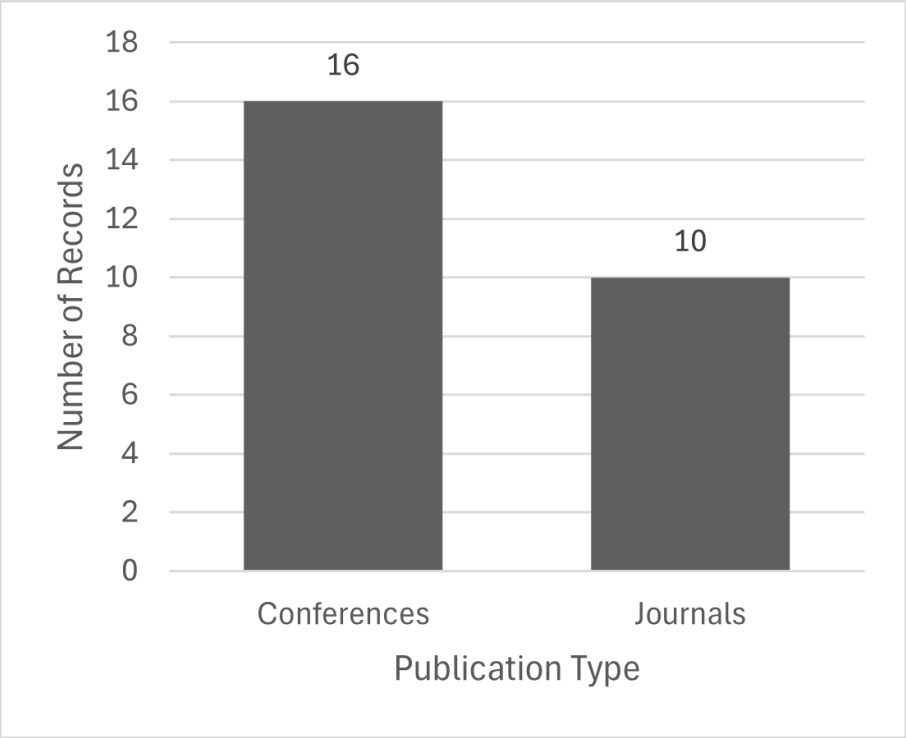


Figure 2.3: Results Included by Publication Source

This distribution of mainly conference papers may reflect the characteristics of the field and the nature of this research, in the sense it is in rapid development, and considered an emergent and niche topic, therefore, making conferences the preferred venue for dissemination of findings and advances.

Regarding the journal publications, an analysis about the journal quartiles was made to assess the quality of the results. Quartile is a metric used to evaluate and rank scientific journals in the Scopus database according to their impact in a particular field of knowledge [44]. All Scopus journals are divided into four main categories (quartiles) - Q1, Q2, Q3, Q4 - depending on their importance and impact. Quartiles are calculated based on SCImago Journal Rank (SJR), a metric that takes into account the number of citations of journal articles and their "value" [44].

Journal quartiles were verified using the Authenticus website. The quartile of one journal wasn't possible to be retrieved, it was thus labeled as N/A. The results, highlighted in the histogram below, show that the included journal publications come from high quality and prominent journals.

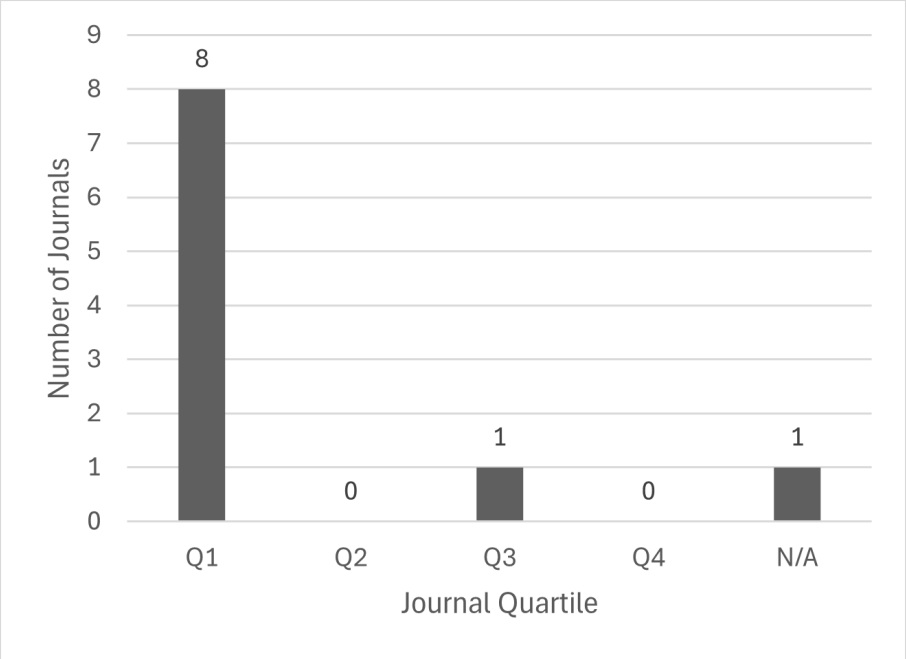


Figure 2.4: Scopus SJR Quartile of the Journals

Having retrieved the full text articles from the included records a multi-criteria analisys was performed.

2.4 Quality Assessment

The Quality Assessment (QA) process is a fundamental step in ensuring the reliability and robustness of a systematic literature review (SLR). In the context of this dissertation, the QA was designed to evaluate the relevance, rigor, and comprehensiveness of the selected studies that focus on the use of gamification in citizen science projects. By identifying strengths and weaknesses within the body of literature, the QA process provides critical insights into the state of the art and guides the subsequent analysis and discussions.

2.4.1 QA Methodology

The QA was conducted using a structured questionnaire consisting of five key questions (QA1 to QA5), each addressing a specific dimension of quality in the evaluated studies. The questions and their respective purposes are outlined as follows:

- **QA1 (Purpose):** Did the study consider the purpose and application domain of the considered gamification strategies in citizen science projects?
- **QA2 (Extend of State of the Art):** Did the study extend the state of the art in gamification of citizen science projects?
- **QA3 (Details on Methodology):** Did the study consider and give details on the methodology used?
- **QA4 (Application):** Did the study present practical applications or real-world examples of citizen science projects where gamification was implemented?
- **QA5 (Limitations and Future Work):** Did the study consider future work and discuss limitation?

The evaluation criteria for each question were categorized as *Yes*, *Partially*, or *No*, indicating the extent to which the study met the respective criterion. A total of 26 studies were assessed based on this framework.

2.4.2 QA Results

The results of the QA are summarized in Table 2.5 and illustrated in Figure 2.5, which provides a graphical representation of the distribution of responses across the five questions.

Question	Response	Count
QA1	Yes	0
	Partially	25
	No	1
QA2	Yes	1
	Partially	15
	No	10
QA3	Yes	20
	Partially	4
	No	2
QA4	Yes	9
	Partially	14
	No	3
QA5	Yes	23
	Partially	3
	No	0

Table 2.5: QA Results Summary

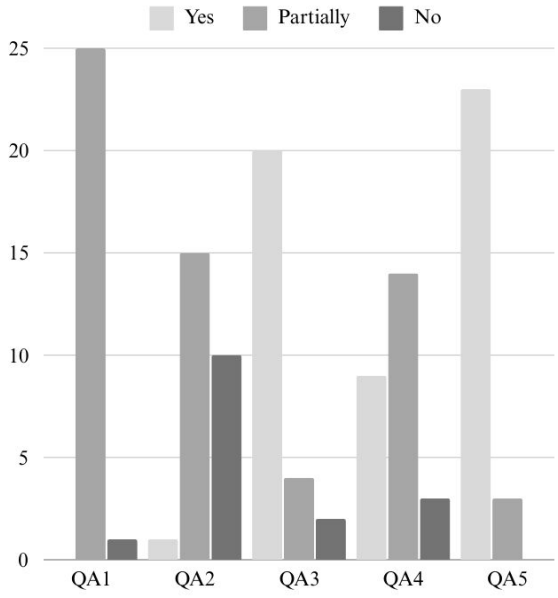


Figure 2.5: Distribution of QA Results

Regarding results shown in Table 2.5 and Figure 2.5, the following observations were made:

- **QA1 (Purpose):** 96% of studies only partially consider the purpose and application domain.

- **QA2 (State of the Art):** 57% of studies partially contribute to new advancements and progress in the state of the art, but also a good amount of studies (38%) merely implement gamification strategies that have been used before.
- **QA3 (Methodology):** The large majority of studies (77%) provide detailed methodologies and on the process they employed.
- **QA4 (Application):** Most studies (88%) showed real-world applications of gamification in citizen science projects, either partially or in high detail.
- **QA5 (Limitations and Future Work):** Almost all of the studies (88%) discuss limitations and propose future work, indicating an awareness of the field's evolving nature.

2.4.3 QA Analysis

The QA process has highlighted notable strengths and identified critical gaps within the evaluated studies, identified below.

The identified **strengths** were categorized into three distinct groups:

- **Methodological Consistency** Most studies (77%) describe the methodologies and processes used in great detail, facilitating their reproducibility [24, 2, 38, 27, 5, 43, 36, 20, 42, 15, 25, 29, 18, 11, 40, 23, 41, 31, 6, 39].
- **Good representation of Practical Applications:** While only 35% of the studies explain in detail the applicability of gamification strategies in real-world citizen science projects, a large amount (54%) also provide examples of practical applications, albeit in lesser detail [24, 2, 38, 27, 5, 43, 36, 21, 16, 19, 30, 9, 37, 39, 6, 31, 41, 20, 40, 11, 18, 29, 25].
- **Acknowledgment of Limitations:** A large majority of studies (88%) openly discuss their limitations and propose future directions, highlighting a critical understanding of challenges when it comes to gamification of citizen science projects [24, 2, 27, 5, 43, 20, 42, 15, 25, 29, 18, 23, 41, 31, 6, 39, 37, 9, 30, 19, 16, 21, 40].

The identified **gaps** were as follows:

- **Unclear purpose:** None of the studies fully consider the domain and purpose of the considered gamification strategies. The vast majority addresses the domain and purpose, but in reduced scope and detail, or only focus on either the domain or the purpose aspect.
- **Lack of Innovation:** All but one of the studies present significant advancements in the state of the art, indicating limited progress in introducing novel gamification strategies [2].

2.4.4 Discussion and Implications

The QA results reveal both strengths and weaknesses within the reviewed literature. Most studies provide a thorough explanation of the methodologies used, and clearly address the limitations and

challenges that still exist. However, they fail to provide a full picture of the domain and purpose of the use of gamification in citizen science projects (QA1), as well as showing a lack of innovation in the field (QA2).

These findings have implications for the reliability of the SLR and underline the need for a more thorough and in-depth consideration of the domain and purpose of gamification as a whole in citizen science projects. Additionally, the limited innovation in the state of art highlight the potential for new gamification strategies to be researched, implemented and their impact analyzed.

2.4.5 Limitations

The QA process itself is subject to limitations. For instance, the categorization of *Partially* responses involves a degree of subjectivity that may affect the consistency of results. Moreover, the framework used does not account for the relative importance of each question, potentially overlooking nuances in study quality.

2.5 Thematic / Chronological / Methodological approach to literature

To ensure a comprehensive and structured analysis of the literature, this review adopts a thematic approach, accompanied by a chronological analysis of the studies and with elements of a methodological perspective where applicable. The studies are organized around the key themes that they explore, reflecting the primary focus areas in the literature.

2.5.1 Thematic Approach

The studies focus on citizen science, gamification, and how the two concepts interact. A common theme is exploring how game elements can be leveraged to increase user engagement and motivation in citizen science projects. Key themes that are discussed among the studies are:

- **Effectiveness of different game elements:** The effectiveness of different game elements like points, badges, leaderboards, narrative, and challenges in player engagement and retention is examined [2, 38, 29, 37, 24].
- **Impact of game elements on citizen science:** The impact of these game elements on various aspects of citizen science, such as data quality, participant retention, and learning outcomes is explored [2, 31, 6, 37].
- **Participant motivation:** It is discussed the importance of participant motivation, both intrinsic and extrinsic, and how different design choices can cater to these motivations [37, 43, 20, 42, 25, 39].

- **Design and implementation of citizen science games:** There is a noticeable emphasis on the design and implementation of citizen science games, including the importance of considering factors like task visibility, feedback mechanisms, and the role of social interaction [43, 20, 41, 39, 37].
- **Challenges of designing effective citizen science games:** Some studies also touch upon the challenges of designing effective citizen science games, including balancing the need for engagement with data quality and scientific rigor [37, 31, 6].

Overall, the sources highlight the potential of gamification as a tool to enhance citizen science projects. However, they also emphasize the need for careful consideration of design choices and a nuanced understanding of participant motivations to create truly successful and impactful gamified citizen science experiences.

2.5.2 Chronological Analysis

To visualize the progress in research in gamification in citizen science, the histogram in Figure 2.6 was created to display the studies' publication year over the last decade.

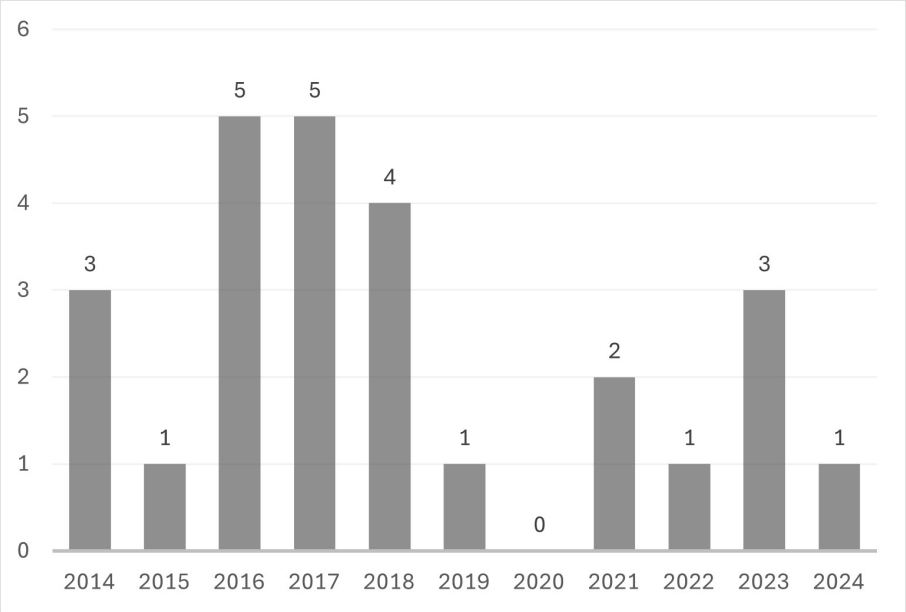


Figure 2.6: Distribution of studies by publication year.

The graph indicates that progress has been continuous over the last decade, with a particular spike between 2016-2018, corresponding to the diversification phase of the research progress. Also noticeable is the lack of studies during 2020, which coincides with the start of the lockdown due to the COVID-19 pandemic. In general, the lockdown impaired research into citizen science projects, especially those that require citizens to mobilize.

2.6 Methodological Perspective

In addition to the thematic organization, a methodological lens is applied to analyze how the studies conducted their evaluations. The methods are examined for their rigor, practical application, and contributions to the state of the art. Key methodologies identified include:

- **Surveys and Questionnaires:** Surveys and questionnaires are widely used to gather data on participant demographics, motivations, and experiences. This method offers valuable insights into player perspectives and helps identify trends in user behavior [43, 42].
- **Analysis of System Logs and Project Records:** This quantitative approach examines platform usage data to analyze participant interactions, task performance, and the effectiveness of specific design elements. Analyzing system logs provides valuable insights into user engagement, data quality, and the impact of various gamification strategies [30, 29].
- **Literature Reviews:** Synthesizing existing research through literature reviews is crucial for identifying key themes, knowledge gaps, and potential avenues for future research. Literature reviews contextualize individual studies and inform the development of robust research designs [38, 37].
- **Qualitative Methods (Interviews, Thematic Analysis):** Qualitative methods like interviews and thematic analysis are essential for exploring the nuanced experiences, motivations, and challenges faced by participants. They provide rich insights that complement quantitative data, offering a deeper understanding of the interplay between motivation, engagement, and learning in gamified citizen science [20].
- **Experimental Studies:** Experimental studies are valuable for isolating the effects of specific game mechanics or design choices. By manipulating variables in a controlled environment, researchers can establish causal relationships between game elements and participant behavior or outcomes [19].

2.7 Trends and Patterns

The studies reveal that gamified citizen science designs must carefully balance motivational strategies, data quality, and design features. Participants are driven by altruism, seeking to contribute meaningfully to scientific research. However, enjoyment and challenge, facilitated by game elements like points and leaderboards, also play a crucial role in sustained engagement. Additionally, a strong sense of community and social interaction fosters a sense of belonging and facilitates collaborative learning.

Balancing these motivations with scientific rigor requires robust data validation techniques. Researchers employ gold standard datasets, expert validation, and targeted recruitment to mitigate biases and ensure data accuracy. Design principles prioritize clear task presentation, achievable

goals, and effective feedback systems to guide participant effort and maintain motivation. Emerging trends point towards incorporating narrative elements and leveraging mobile technology and augmented reality, promising more immersive and accessible experiences for participants in the future.

2.8 Gaps Identified

While the studies offer valuable insights into the trends and challenges of gamified citizen science, several key areas require further investigation to advance the field and fully realize its potential.

- **Long-term Studies on Motivation and Engagement:** Existing research primarily focuses on short-term impacts. More long-term studies are crucial to understand the evolution of participant motivation over extended periods, identify factors contributing to sustained engagement, and assess the long-term benefits of participation.
- **Rigorous Evaluation of Game Element Effectiveness:** The studies often highlight the positive impacts of gamification but lack a systematic evaluation of individual game elements. Future research should isolate and compare the effects of specific game mechanics on participant behavior, data quality, learning outcomes, and overall project success.
- **Diversity and Inclusion in Gamified Citizen Science:** The studies tend to focus on general participant populations. Further research should investigate the differential impacts of gamification on diverse demographic groups. Understanding how factors like age, gender, cultural background, and prior gaming experience shape participant experiences is crucial for promoting inclusivity and broadening participation.
- **Sustainable Funding Models and Resource Allocation:** The financial sustainability of gamified citizen science projects requires attention. Research exploring innovative funding models and strategies for effectively allocating resources to support long-term engagement and project development is essential.
- **In-depth Exploration of Ethical Considerations:** While some studies touch upon potential biases, a more comprehensive examination of ethical implications is needed. This includes addressing data privacy concerns, ensuring informed consent, and mitigating potential exploitation of participant labor to foster responsible and equitable practices within the field.

2.9 Summary

This chapter reviewed gamification in citizen science projects, gamification strategies implemented in citizen science games and their impact on player retention and engagement. It also identified key challenges, trends, and gaps in the existing literature.

The included studies tackle several gamification strategies that have been implemented in differen tcitizen science projects, such as leaderboards, missions, points and badges. They refer to existing projects where gamification was employed such as Eyewire and Foldit and their impact on player retention and engagement. They also provide insights on the benefits of using gamification in citizen science projects, and on the necessary balance between intrinsic and extrinsic motivations to keep in mind while implementing gamification strategies.

Trends and gaps were identified in the literature. Trending patterns are the careful consideration of the balance between player motivations, design features, and data quality, as well as the more recent trends of the use of augmented reality and mobile technology. Gaps include the lack of long-term studies, a more rigorous evaluation of the effectiveness of game elements, and issues regarding diversity and inclusion, sustainable funding models, and further exploration of ethical considerations.

Finally, combining thematic organization with a methodological perspective, and integrating chronological analysis and progress provided a structured and holistic review of the literature. This multi-dimensional approach ensures that the key contributions, trends, and gaps in gamification strategies for citizen science projects are clearly identified, forming a strong foundation for subsequent analysis.

Chapter 3

State of the Art

3.1 Theoretical Framework

To understand the context of this work, it is essential to define and clarify the concepts that make up the foundation of the research. This section lays out the concepts of the theories that underpin the gamification strategies, and the concepts of a player's intrinsic and extrinsic motivations. These concepts form the backbone of gamification in citizen science and how gamification strategies are implemented in citizen science projects.

3.1.1 Theories Behind Gamification Strategies

Gamification in citizen science aims to enhance participant engagement and improve data quality by incorporating game elements into scientific research projects [2]. The implementation strategies of these game elements are backed by a player's intrinsic and extrinsic motivations, such as altruism and curiosity, which are explored in further detail in section 3.1.2, and also by theories that posit on a individual's psychological needs and cognitive loads. These behavioral theories are heavily discussed in [23]. This study also elaborates on how these theories were adopted and used to refactor and improve the user interface of a citizen science game, Foldit. The theories are identified and described below:

- **Self-Determination Theory (SDT):** This theory, frequently applied to gamification in citizen science, posits that individuals are driven by three basic psychological needs: competence, autonomy, and relatedness. Citizen science games, often requiring significant mental effort, primarily draw participants motivated by a love for science rather than the game itself. Applying SDT principles can enhance engagement by fostering feelings of competence through skill development, providing choices and control to support autonomy, and building a sense of community to fulfill the need for relatedness [23].

- **Cognitive Load Theory (CLT):** This theory focuses on managing the cognitive demands placed on participants during learning. Citizen science games, especially those involving complex scientific concepts, need careful design to avoid overwhelming participants with

excessive information. CLT principles can be applied by breaking down information into manageable chunks, providing clear instructions, and using visual aids to reduce cognitive load and support effective learning [23].

3.1.2 Intrinsic and Extrinsic Player Motivations

Intrinsic motivations in citizen science games come from the inherent enjoyment and satisfaction that players find in the activity itself [38, 40]. These motivations can significantly impact their engagement and overall experience in citizen science games [38, 40, 5, 23]. Some of the key intrinsic motivators are as follows:

- **Altruism/Contribution:** Many players are driven by a strong desire to contribute to a worthy cause and support scientific discoveries [43, 42, 37]. They find deep satisfaction in participating in something larger than themselves and making a meaningful impact on the world [37]. This sense of purpose and knowing that their efforts are helping advance scientific knowledge is a powerful incentive [42, 39].
- **Interest/Curiosity:** A genuine interest in the scientific domain is a potent intrinsic motivator [37, 20, 42, 23]. Players are drawn to projects that align with their personal interests or offer opportunities for self-learning [43, 42, 6, 39, 37]. They are eager to explore, understand, and gain knowledge about the subject matter [37, 43, 42, 6, 39, 38, 23]. Providing players with in-depth information about the science behind the game can further enhance their motivation and sense of purpose [23, 6]. The challenge of acquiring knowledge is itself rewarding for these players [37, 42, 23, 6].
- **Fun/Enjoyment/Challenge:** While the primary motivation might be altruistic or scientific, the enjoyment derived from the gameplay itself is crucial for sustained engagement [37, 20, 43, 39, 38, 42]. Players find the challenge, problem-solving aspects, and sense of achievement derived from successfully completing tasks to be inherently rewarding [37, 42, 23, 6, 21]. The gamified environment offers a safe space for trial and error, where players can experiment and learn through their actions [38].
- **Community/Relatedness:** The social aspect of citizen science games, fostering a sense of community and belonging, can also be intrinsically motivating [37, 20, 42, 23, 43, 39]. Players value the opportunity to connect with like-minded individuals, share experiences, and collaborate towards a common goal [37, 20, 23, 43, 42, 41].

Extrinsic motivations in citizen science games originate from external rewards or outcomes associated with playing the game [43, 37]. These elements often provide a sense of achievement, progression, or recognition that can drive engagement [29, 37], particularly for players who might not be intrinsically motivated by the scientific subject matter [27, 43, 31, 37, 30]. Some examples of a player's extrinsic motivations are described below:

- **Game Elements:** Game elements such as points, leaderboards, badges, rewards, competitions, and time constraints, can significantly enhance engagement and encourage continued participation [2, 43, 19]. These game mechanics provide a sense of achievement, progression, and recognition that can be highly motivating for players who enjoy tracking their advancement and comparing their performance with others [24, 37].

- **Financial gain:** Although less common in citizen science games than other crowdsourcing platforms, financial gain can also be a motivating factor, particularly for individuals who place a high value on monetary rewards [39]. However, the impact of financial incentives must be carefully considered, as they can sometimes undermine intrinsic motivations [37].

In summary, intrinsic motivations stem from the inherent satisfaction and enjoyment derived from the activity itself, while extrinsic motivations are driven by external rewards or outcomes. Both are important for understanding player engagement in citizen science games.

It's also important to recognize that intrinsic and extrinsic motivations are not mutually exclusive. Players are often driven by a combination of both. For instance, a player might be primarily motivated by a desire to contribute to science but also enjoy the challenge of earning points and badges. Just as important is the need to balance intrinsic and extrinsic motivations when designing citizen science games to ensure both scientific value and player engagement.

3.2 Gamification in Citizen Science

Gamification in citizen science refers to the integration of game elements into scientific research projects to enhance engagement, motivation, and participation among volunteers [2, 38, 37]. The goal is to make contributing to science more enjoyable and rewarding, thereby attracting a wider range of participants and improving the quality and quantity of data collected [2, 41, 37, 42]. These game elements, often referred to as non-diegetic rewards, can include points, badges, leaderboards, levels, challenges, and narrative elements [2, 19]. Incorporating these elements can significantly increase the fun factor, encourage friendly competition, and foster a sense of achievement among participants [29, 31, 42]. In order to define and elaborate on the current landscape of gamification in citizen science, subsection 3.2.1 discusses gamification strategies that have been used and are implemented in active citizen science projects, and subsection 3.2.2 identifies currently active citizen science projects and provides a description on each of them.

3.2.1 Gamification Strategies

A gamification strategy refers to the deliberate application of game design elements and principles in non-game contexts to motivate, engage, and influence the behavior of individuals [16, 29]. At its core, a gamification strategy leverages the natural human inclination toward achievement, competition, and rewards to drive participation and desired outcomes [29, 19, 2]. Commonly implemented gamification strategies are listed below:

- **Points Systems:** Points systems offer a quantifiable measure of progress and achievement within the system [37]. Users are awarded points for completing tasks or milestones. This provides a clear indication of their contribution and allows them to track their progress [43, 24, 16].
- **Leaderboards:** Leaderboards display rankings of participants based on their performance, typically measured by accumulated points [43, 19]. This introduces an element of competition and encourages users to strive for higher rankings [43, 24, 15, 41, 16].
- **Badges:** Badges serve as visual representations of accomplishments, awarded for reaching specific milestones or completing particular achievements [37]. They offer a sense of recognition and reward for users' efforts [43, 24, 2].
- **Status and Roles:** Status and roles can be granted to users based on their performance or contributions [24, 41]. This can involve assigning them special titles or roles within the community, providing them with a sense of progression and recognition [24, 41, 37].

In addition to these common strategies, other gamification elements have also been explored and applied in citizen science projects, such as:

- **Challenges and Missions:** Challenges and missions involve presenting participants with specific goals or tasks to complete [41, 5]. This can motivate users by providing a sense of purpose and direction.
- **Time Constraints:** Time constraints are implemented through deadlines or time limits for completing tasks or challenges [24]. This can create a sense of urgency and encourage users to engage promptly.
- **Narrative Elements:** Narrative Elements are incorporated to enhance engagement by providing a more immersive and enjoyable experience [5, 40, 21]. This can involve weaving a storyline into the project or incorporating elements of storytelling to make the activity more engaging [5, 40, 21].

3.2.2 Citizen Science Games

In this subsection, some examples of active citizen science games are listed. These citizen science projects were built with gamification in mind, and have managed to make successful scientific contributions via its players' continuous engagement. They maintain an active player base that to this day keep playing and assist in scientific progress. These games have been referenced and studied extensively, including for example the impact the implementation of their game elements has had on player engagement and retention.

The following descriptions of these games include their scientific objectives, the gamification strategies that have been implemented in each, and a summary of the players' contributions to science.

3.2.2.1 Foldit

Foldit has been a subject of study as a successful example of gamification in a citizen science project [39, 9]. Foldit is a citizen science game that engages players in solving the complex challenge of protein folding. Players manipulate 3D protein structures by twisting, pulling, and adjusting their components to find the most stable configurations, corresponding to a protein's native state. This process is vital for understanding biological functions, diseases, and drug design.

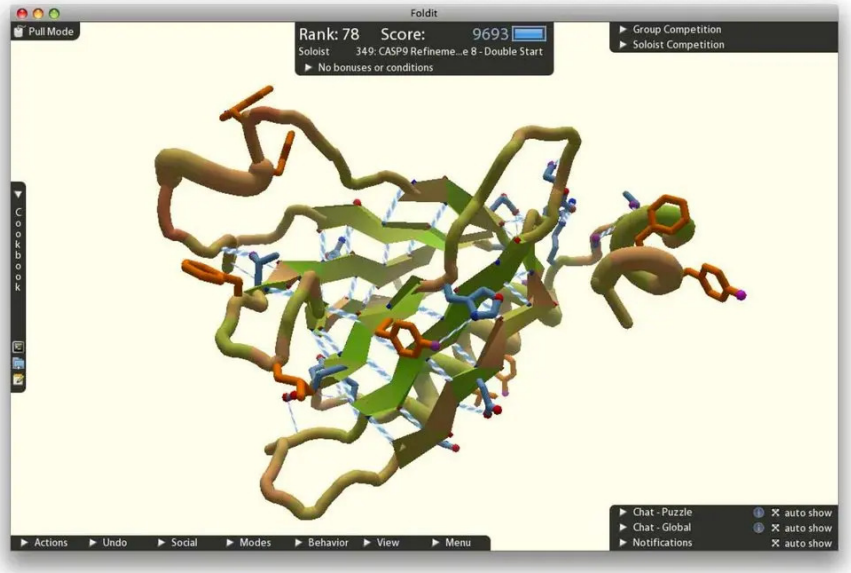


Figure 3.1: Foldit game interface.

The game includes elements like challenges and puzzles, a scoring system, and leaderboards to motivate players. Real-time feedback helps refine strategies, while tutorial levels introduce scientific concepts. Players can collaborate through teams and community challenges, directly contributing to research efforts like designing antiviral proteins or stabilizing vaccines.

Foldit has made significant scientific impacts, including solving the structure of an HIV-related enzyme in just three weeks, a problem that had stumped researchers for years. Insights from player strategies have improved automated protein-folding algorithms, bridging human intuition and machine learning. Beyond discoveries, Foldit has engaged the public with science and demonstrated the power of gamification in tackling complex scientific problems.

3.2.2.2 Eyewire

Studies have researched into the influence of the gamification strategies implemented in Eyewire on player engagement and the quality of their contributions [43, 42, 37]. Eyewire is a citizen science game where players map the connections of neurons in the brain by tracing their structures in

[0]Figure 3.1 retrieved from https://www.nytimes.com/2010/08/10/science/10gamers.html

3D reconstructions. This collaborative effort helps researchers understand how the brain processes information and advances neuroscience and artificial intelligence.

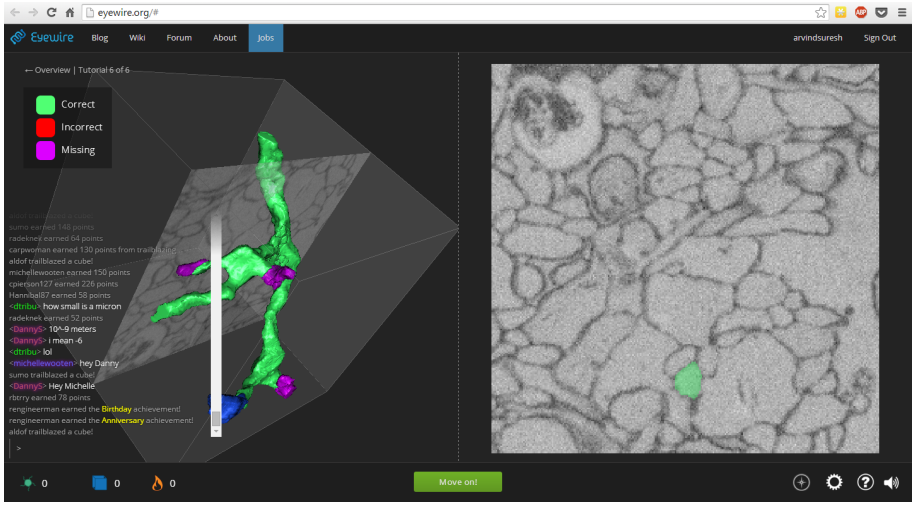


Figure 3.2: Eyewire game interface.

The game includes challenges where players trace neural pathways, earning points for accuracy. Leaderboards, ranks, and visually stunning representations of brain structures keep players engaged. Community features, like chat rooms and progress tracking, encourage collaboration and create a sense of achievement.

Eyewire has significantly impacted neuroscience by contributing to the mapping of neural circuits and discovering new neuron types. The data generated by players also improves AI algorithms for analyzing complex biological structures. Beyond research, the game educates the public about brain science, making cutting-edge research accessible while inspiring global participation.

3.2.2.3 Project Discovery

The learning curve of new players with the game elements and mechanics of Project Discovery has been a subject of study [20].

Project Discovery is a citizen science initiative integrated into the MMORPG EVE Online, where players assist with real-world scientific research while engaging in the game. It has tackled diverse scientific challenges, including identifying exoplanets, analyzing protein structures, and mapping human cell patterns.

The game includes tasks seamlessly woven into EVE Online's interface, allowing players to analyze datasets like light curves from stars or cellular microscopy images. Players receive immediate feedback on their contributions, earn in-game rewards such as currency and items, and see their progress tracked through levels and ranks. Collaboration is encouraged through shared discoveries and leaderboards, fostering a sense of community.

[0]Figure 3.2 retrieved from https://www.discovermagazine.com/mind/citizen-powered-neuroscience-with-project-eyewire-using-your-neurons-to-map-the-brain

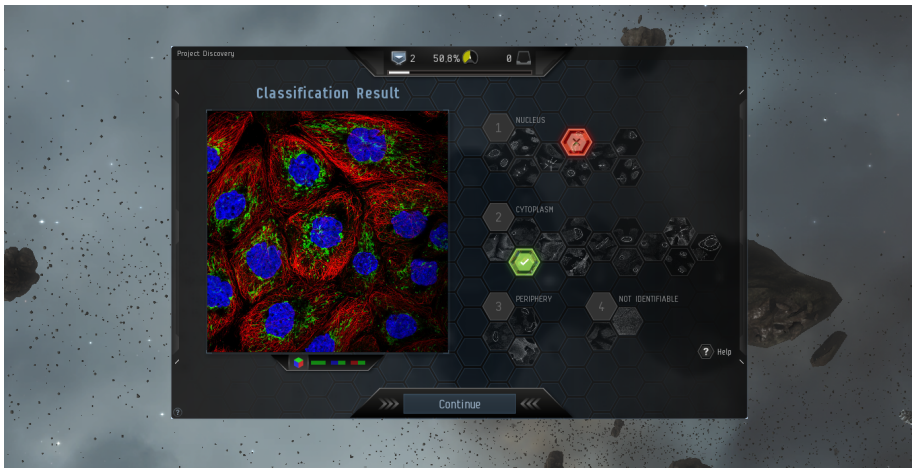


Figure 3.3: Project Discovery game interface.

Project Discovery has significantly impacted science by crowdsourcing data analysis to accelerate discoveries. For example, players have helped refine exoplanet detection methods and contributed to protein research critical for medical advancements. This innovative integration has also brought scientific awareness to a vast gaming audience, demonstrating how entertainment can drive real-world research.

3.3 Augmented Reality in Citizen Science Games

The application of Augmented Reality (AR) in citizen science games is a topic that hasn't been thoroughly researched. However, the available information suggests that AR holds potential for enhancing engagement and providing unique experiences in citizen science games.

Tile-o-Scope AR (TOSAR) [27] is an AR tabletop game toolkit designed for image classification citizen science games. Players use a mobile device to view images displayed on physical tiles with AR markers, making matches between tiles based on image categories. This combination of physical and digital elements creates a more immersive and interactive experience than traditional browser-based games.

While the browser interface promoted rapid and accessible play, leading to faster completion of the scientific task (image labeling), the AR version fostered more thoughtful engagement and memorability in relation to the citizen science content.

It is suggested that the strength of AR lies in its ability to create "leisurely toy" experiences, making it well-suited for educational contexts, museums, and citizen science events [27]. However, the authors also acknowledge potential drawbacks of AR, such as distractions from the core scientific tasks and overlapping labor, where participants might focus more on the technology than the science.

[0]Figure 3.3 retrieved from https://www.eveonline.com/news/view/project-discovery-needs-you

Overall, the study suggests that AR can offer unique benefits for citizen science games, particularly in promoting engagement and thoughtful interaction with scientific content. But it's important to carefully consider the context and design the AR experience to mitigate potential distractions and ensure the focus remains on the scientific goals.

3.4 Summary

To summarize this chapter, there was an outline of the theoretical framework on which gamification strategies are designed and conceptualized. It consists on leveraging a player's intrinsic and extrinsic motivations, ensuring their careful balance, while also taking in consideration behavioral theories such as SDT and CLT.

Game elements and gamification strategies that have been studied and used in citizen science projects were identified. Common elements include leaderboards and point systems, but others have also been considered, albeit more rarely, such as narrative elements.

Citizen science games referenced in the studies were described, as well as their success as citizen science projects and the contributions they've made to their respective research fields.

Finally, the research on the use of Augmented Reality in citizen science games was laid out, and it concluded that AR does have potential in citizen science, with the ability to make more enjoyable experiences for the players. However, it was also highlighted that the context and design of the AR experience must be carefully considered, to avoid distractions and the focus of the players diverting from the scientific contributions.

Chapter 4

Gamification in JellyfishGO!

4.1 Introduction

This chapter lays out and describes in detail the methodology to be applied in this work to ensure transparency, replicability and validity. The chosen methodology is appropriate to address the research questions as it will focus on the introduction of gamification strategies in the game of JellyfishGO! and then observe their impact on player engagement and retention.

Currently, the JellyfishGO! project is at a very early stage. The game exists with barebones mechanics such as jellyfish catching and a prototype version of gyms. The next step in the development of JellyfishGO! is the implementation of further gamification strategies, which is what this work focuses on. Several game elements were listed for possible implementation, based on the literature review as well as current gamification trends in modern games and citizen science projects. The strategies to be introduced in JellyfishGO! are as follows:

- **Teams:** The concept of in-game teams will be introduced, these will function together with other game elements, such as leaderboards and points, in order to promote both cooperation and competition [43, 37, 9]. Players will be associated according to their geographical location - players close to the coastline will team up with players further away from the coast. This association logic works according to another concept of JellyfishGO!, wherein players located away from coastlines can catch digital versions of jellyfish that can then be associated with its real world counterpart via a sighting from a player closer to the coastline.

- **Points system:** The points system will drive most of the competitive and cooperation aspect of the game [43, 37, 9]. Players will be able to compete for highest point tally in the leaderboards, while at the same time cooperating as a team to gain as many points as possible [43, 37, 9]. Players will be able to gain points by making contributions, and by completing missions [43, 37, 9].

- **Missions/Tasks:** The game will have missions/tasks that players can complete to gain points [5, 37, 19]. These will come in varying difficulty, where the reward is directly proportional to the difficult of the mission/task. The missions/tasks will revolve around contributions.

- **Leaderboard:** A leaderboard will be included in the game. Like the points system, it will promote both cooperation and competition among the players [43, 37, 9, 42, 16]. There will be an individual and team leaderboard, as well as weekly and overall leaderboard. Players and teams will be ranked according to their points, and rankings will be included as well.

These gamification strategies were chosen for their inter-connectivity, for being present in other successful citizen science games, and at the same time for being feasible to be implemented in the amount of time allotted for the development of the game.

4.2 Method

The research method used in this work is the Design Science Research (DSR) method. This paradigm is particularly suited to the objectives of this study due to its focus on creating and refining practical artefacts to solve real-world problems [7]. Gamification in citizen science requires a structured, iterative approach to ensure that the game effectively engages users while meeting scientific objectives. DSR's cyclical process of design, implementation, and evaluation aligns perfectly with this need, allowing for continuous refinement based on user feedback and observed outcomes.

A DSR project is composed of six dimensions. In the context of this research, they are defined as follows:

- **Problem:** The problem at hand is to study the impact of the introduction of gamification strategies in player contribution, retention and engagement in the JellyfishGO! game, as defined by the research questions in section 1.4.
- **Input Knowledge:** The input knowledge are the observations and conclusions made during the literature review, such as gamification strategies previously used in other citizen science games, and evaluation methods utilized to analyze their impact on player retention and engagement.
- **Research Process:** The research process consists of two main stages: the design and implementation of the selected gamification strategies; followed by the analysis of their impact via an experimental study.
- **Key concepts:** The most important concepts are those of the player motivations, both intrinsic and extrinsic, as well as those of the game elements themselves. The latter being important to understand what is being implemented, and the former to provide reasoning and foundation behind the implementation of gamification strategies.
- **Solution:** The solution resides in the introduction of the selected game elements into the existing JellyfishGO! game. Their introduction will provide players with incentives to play and to keep playing the game, while making contributions.

- **Output Knowledge:** The output knowledge from this research will be the impact these game elements have on player contribution, engagement and retention, and consequently the role they play in the success of a citizen science game project.

4.3 Solution Requirements

Before any development into the solution, it was necessary to define the necessary requirements for the solution to meet. This is an essential step to the development process of the solution, and of the prototype, as these requirements provide clear and concrete goals, functioning as guidelines for the process. The requirements for the implementation of the game elements revolved around three main fields:

- **Core Mechanics:** The already existing mechanics in the game that the game elements will be built upon, thus these mechanics are referred to as the core mechanics. More specifically, the requirements in this field touch on the capture system for both real and virtual models of jellyfish, to refine and enhance it so that the other game elements can be implemented around it.
- **Game Elements:** The new game elements that are going to be introduced into the game - leaderboards, badges, missions and teams. The requirements for these new game elements focus on developing the key features for each of them that will allow them to function as envisioned, taking into the consideration time and resource constraints.
- **Supporting Systems:** Necessary systems, beyond the scope of the game application itself, that the game elements depend on. These systems include an online database to hold all the players data that will be used for analysis, and an API that the game application can use in order to communicate with the database, to fetch and send data.

Besides categorizing the requirements by their respective field, they were also ordered in terms of priority. This requirement prioritization further assisted in guiding the development process of the prototype, by identifying the key and essential features that must be implemented in order to achieve a working prototype. Three priority levels were defined to order the requirements:

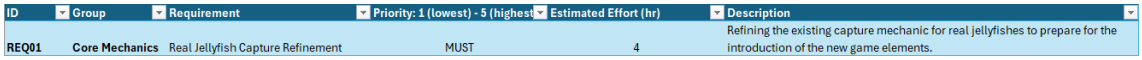
- **MUST:** These requirements are of the highest priority, identifying the most important features that must be focused on and implemented into the JellyfishGO! game.
- **SHOULD:** These are middle priority requirements. They aren't essential to the proper functionality of the game elements and systems, but their implementation would significantly enrich and complement the key features.
- **COULD:** The lowest priority requirements. These requirements aren't essential to the proper functionality of the application, similar to the middle priority requirements. The difference between these requirements and the middle priority requirements is that these

requirements wouldn't meaningfully enrich the key features and systems, working more as polish and providing completeness to the systems.

An Excel spreadsheet was created that identifies and describes each of the solution's requirements. Furthermore, the spreadsheet also includes a user story for each requirement in order to justify the inclusion of the requirement in the solution and to better clarify the requirement's purpose and goal. Table 4.1 lays out the structure of a requirement in the spreadsheet, and figure 4.1 shows one of the requirement present in the spreadsheet.

Table 4.1: Requirement structure

ID	A unique identifier for the requirement
Group	Category or field where the requirement falls into
Requirement	The name of the requirement
Priority	The priority level of the requirement
Estimated Effort	An estimate of the required effort to implement the requirement in hours
Description	A description of the requirement



ID	Group	Requirement	Priority: 1 (lowest) - 5 (highest	Estimated Effort (hr)	Description
REQ01	Core Mechanics	Real Jellyfish Capture Refinement	MUST	4	Refining the existing capture mechanic for real jellyfishes to prepare for the introduction of the new game elements.

Figure 4.1: Example of a requirement identified in the spreadsheet

As mentioned above, for each identified requirement in the spreadsheet, a user story was created to provide an example of the intended usage and behavior of the implementation of the requirement. Table 4.2 describes the structure of a user story used in the spreadsheet.

Table 4.2: Requirement structure

ID	A unique identifier for the user story
Requirement(s)	The requirement(s) that are involved in the user story
Actor	The entity that performs the action in the user story
Name	The name of the user story
Description	A description of the action in the user story
Pre-condition(s)	Condition(s) necessary to be met for the action in the user story to take place
Main Flow	Sequence of steps that the entity takes to complete the action, assuming everything goes as expected
Alternative Flow	Optional sequence of steps that the entity takes that deviate from the main flow, achieving the same goal or handling exceptions
Post-condition(s)	Condition(s) necessary to be met in response to the action taking place
Validation	Criteria that define the successful implementation of the user story and of the requirements involved

4.4 Solution Description

The solution to be implemented leans heavily on concepts that were identified in chapter 3. The game elements chosen to be introduced into JellyfishGO! aim to tap on both the player's intrinsic and extrinsic motivations. For example, with the missions system the player is challenged to complete their missions in order to retrieve the rewards, or the teams system that promote the player's feeling of community and cooperation.

In the same vein, the solution also takes inspiration from other successful citizen science games. Similar to them, JellyfishGO! will rely on player cooperation and competition, two factors that have proven to be very effective in motivating and retaining players in the citizen science games identified in section 3.2.2.

The requirements for the solution were thus designed having in mind these concepts and other games. The game elements to be implemented in JellyfishGO! will attempt to explore as much of the player's intrinsic and extrinsic motivations, while heavily betting on the player's sense of competition and cooperation akin to other successful CSGs.

4.5 General Methodology

The entire process is divided into two parts: the development of the prototype, followed by testing the prototype with real players. The prototype will essentially be made of the existing game but with the introduction of the new game elements, alongside the supporting systems required for the new elements and in-game data collection. More details on the prototype can be found in section 4.6.

A case study will then take place, where volunteer players will be gathered to playtest the developed prototype and provide data that will then be used to answer the research questions. This case study will be important not just to answer the research questions but also to gather insights for the future development of JellyfishGO!. Details on the experimental protocol of the case study are present in chapter 5.

4.6 Prototype

The prototype developed contains two main systems:

- **Server:** The server system is made of two core components - the database and the API. It is deployed in an Azure cloud service, to provide greater availability. As for the components, the database maintains in-game player and team data, specifically storing information which is then used for analysis, such as the total number of jellyfishes caught by players, their total score, a team's total jellyfish matches, etc. The API is made of several endpoints from which the game client can communicate with, either to request data from the database, or to update with new data.

- **Client:** The client system is essentially the mobile application itself. It contains and controls all the game logic, except for the team jellyfish match mechanic, which is done on the server side. The client keeps a local copy of the player data in the player's mobile device in order to reduce the number of requests made to the API, which in turns makes the game run faster. The local copy is kept synchronized with the database data upon player login and player logout or exiting the game. There is one instance of a client for every player, therefore, a client can also be thought of as a player.

Figure 4.2 shows a diagram of the overall system architecture to better visualize their composition and communication between each other. In the diagram, the term players is used instead of clients, but they can be used interchangeably.

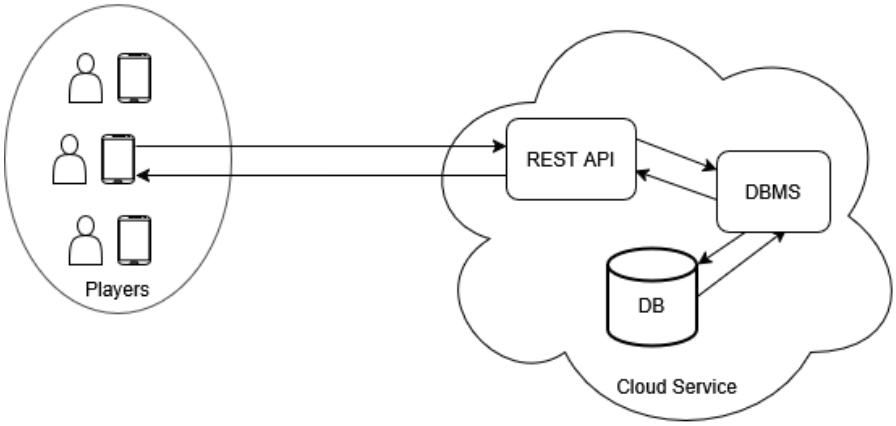


Figure 4.2: JellyfishGO! system architecture.

All of the clients instances are in communication with the single server instance hosted in the Azure cloud. The communication is bi-directional - a client sends a request to the server, and the server responds, depending on the client request, by either sending the requested data back to the client, or by informing the client of a successful database update. The clients communicate with the server solely via the API and its defined endpoints.

On the server side, the API then communicates with the DataBase Management System (DBMS), where all the stored procedures are located. The API calls a specific stored procedure, depending on the client request, and the stored procedure attempts to execute all of its statements. All of the statements in the stored procedures are encapsulated in transactions, one transaction per stored procedure. If any statement fails, the whole transaction is rolled back, thus ensuring data integrity and consistency. If the transaction is successful, it returns any data fetched from the database back to the API, which in turn is returned back to the client that made the API request.

A sequence diagram in figure 4.3 presents the communication between the game's systems when a player captures a jellyfish. As stated above, the client communicates with the API, then the API contacts the DBMS which will perform the operations in the database before returning

data back to the API, and finally the API sends data back to the client. Other events, such as a player login, follow the same sequence of communication.

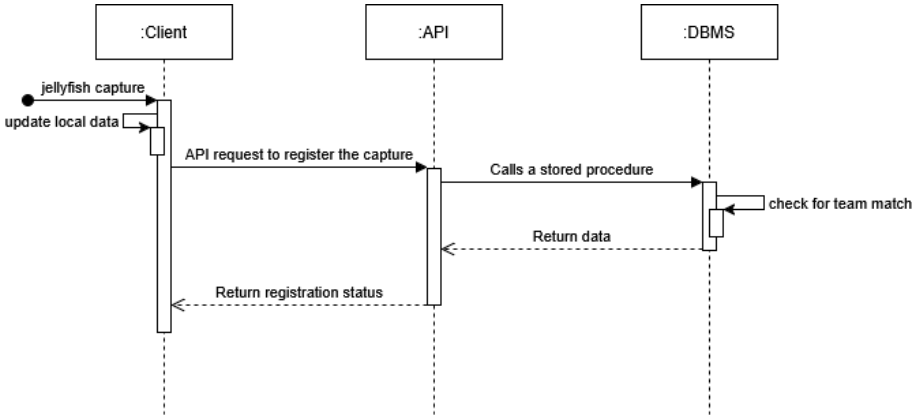


Figure 4.3: Jellyfish capture sequence diagram.

4.6.1 Development Process

The development process comprised of three stages, described below in order:

1. **Development of the new game elements:** The game elements to be introduced into JellyfishGO! were developed as independent modules, to then be integrated and connected into the existing application codebase.

2. **Creation of the database and API:** This stage includes the design of the relational model to be used for the construction of the database, the definition and implementation of the operations to be executed on the database, and the creation of the endpoints for the API to be used by the clients for communication with the server.

3. **Refining existing mechanics and integrating the new game elements:** The last stage is where the new elements were integrated into the existing codebase. Prior to their integration however, the existing mechanics, such as the capturing mechanic and spawning mechanic had to be refined and reworked to accommodate the integration.

The new game elements could have been implemented directly into the existing codebase, however the handout of the existing codebase was only finalized late into the development process. As such, in order to avoid the development from pausing, the decision was made to develop the elements as modules that could then be integrated into the existing codebase whenever it would be delivered. The game elements were also developed independently from each other so they could be developed in parallel, making this stage of the development process more efficient. There are no direct dependencies between the game elements, and this fact made the parallel development possible.

For debugging purposes, the database and API were initially made available locally in a local network, and through the use of the ngrok tool, a port was opened to allow communications over

the internet. After the conclusion of the development of the database and the API, they were deployed and made publicly available in the Azure cloud.

Regarding the refactoring and refining of existing mechanics, some had to be completely rebuilt from the ground up, while others required only a few adjustments. For example, the spawning mechanic for the jellyfishes was fully rebuilt, making use of the Niantic's database for points of interest around the world to place the jellyfishes on the world map. In contrast, the capture system needed only a few changes to account for the acquisition of player points upon a jellyfish capture, and for the checking of a new team jellyfish match.

4.6.2 Technologies and Resources

The technologies used in this development process mirror the ones that had been used in the already existing JellyfishGO! application. This reduces overall development time and complexity as there is little to no need of conversion of existing codebases, and maintains consistency along the tech stack. Therefore, the technologies used in this development process were the Unity game engine, alongside the Niantic Lightship Maps and ARDK frameworks for Unity.

The Unity game engine is the core technology that powers the JellyfishGO! game, providing the core framework and game logic for the game application, built using the C# programming language. The Niantic frameworks provides additional tools for game development with a focus on AR, from which the main mechanic of JellyfishGO! built upon, the jellyfish capture system.

Futhermore, in regards to the external systems, the database was created using SQL Server, which allows for the creation of stored procedures, a feature heavily used for this project. The API was developed in JavaScript using the Node.js framework and the express.js library for the definition of the routes and endpoints. This choice for the API tech stack is based on preexisting familiarity, which made the creating and development process faster. The database and API were then deployed using Microsoft Azure cloud services.

In addition to aforementioned technologies, Git was also utilized as a version control and organization system. The inclusion of a version control technology benefited the development process by facilitating collaboration and the branching and merging of code.

Regarding resources, the development counted with the contribution of four additional members, these being bachelor students in their final year. The game elements to be introduced were split among these additional members, each in charge of implementing the game element they became responsible for. While this increased team size meant that more features could be developed in the time allotted for development, it also required increased organization and coorditination so that the entire development process could flow smoothly. This is another key reason for the usage of a version control system like Git.

4.6.3 Implementation Results

In this subsection, some images are presented to showcase the results at the end of the prototype development process. The images are screenshots taken from a mobile device running the production version of the prototype, the same that the participants later played during the case study.

Figure 4.4 shows the main screen of the new version of JellyfishGO!. The generated virtual map is based on the player's current geographical coordinates, and the jellyfish markers spread out over the map represent "capture spots". The player can press on a marker, preview the jellyfish specie that resides in that location, and choose to capture it. At the bottom are three buttons, each redirecting the player to the views of the newly implemented game elements.



Figure 4.4: JellyfishGO!'s main screen.

The leaderboard view can be seen in figure 4.5. It displays the top 50 players or teams in terms of score, depending if the current leaderboard being viewed is the individual or team leaderboard respectively. At the bottom, the player can see their own position and score. The player and team data is fetched from the server every time the view is opened, in order to display the most up to date information.

Figure 4.6 shows the missions view, where the player is able to see their currently active missions as well as track their current progress of each mission. The player is also able to view a history of completed missions. The player can have up to 3 active missions at once, and each mission can be completed once. When a mission is completed, it is replaced by a new mission not yet completed by the player.



Figure 4.5: JellyfishGO! leaderboard view.

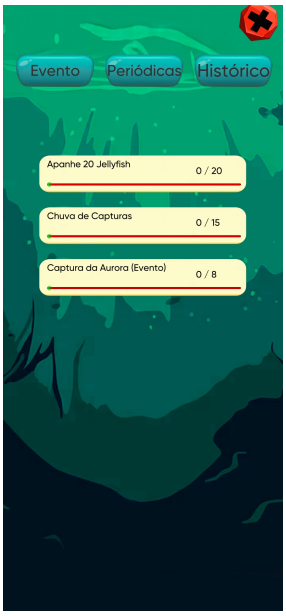


Figure 4.6: JellyfishGO!'s missions view.

The player can see their team's details such as team points, team matches and team members in the view shown in figure 4.7. Like with the leaderboard data, the team data is also fetched from the server every time the view is opened to ensure the most up to date data is shown to the player.

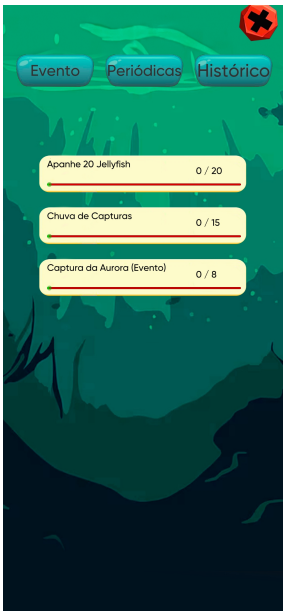


Figure 4.7: JellyfishGO!'s teams view.

4.7 Summary

This chapter detailed the methodological approach, including the research method, the identification of the gamification strategies to be implemented, it described the initial process of identifying the solution requirements based on the analysis of the state of the art, and finally it discusses details about the prototype developed for the solution. The reliance on the DSR methodology ensures a robust and comprehensive analysis.

Careful consideration was taken when selecting the game elements to be introduced in JellyfishGO!. Namely, so each element can work together with the others. For example, having a point system that will be used to rank players in the leaderboard, and missions that will earn the player points. This will help to build a solid gameplay loop, which can then be further expanded in the future.

The developed prototype includes the refined existing game mechanics, such as the capture system and the spawning of jellyfish markers around the player's location, as well as the new game elements. It also includes the API and database cloud server, used for in-game data collection and for the teams and leaderboard systems to fetch data.

The proposed solution has a significant potential to improve player engagement and retention levels of JellyfishGO! and provide valuable insights to gamification in citizen science. By making use of effective gamification strategies, this research will aim to make the JellyfishGO! game succeed in engaging and retaining players, and with their contributions make significant advancements and progress into the development of the jellyfish forecasting system.

Chapter 5

Experiment Protocol

5.1 Test Methodology

The main goal of this methodology is to evaluate the impact of the newly introduced game elements on player engagement and retention, in order to answer the research questions presented in section 1.4. In this context, determining whether players feel enjoyment, are engaged while playing and demonstrate interest in keeping on playing the game due to the addition of the new gamification strategies is crucial to understanding whether their addition was successful (in terms of positive impact) or not.

5.2 General Description

The experiment aims to address the research questions, as well as some additional questions, such as:

- **Question 1:** Is the system valid in terms of usability?
- **Question 2:** What is the distribution of Bartle's player types among the players?

To ensure meaningful results, the game is validated among voluntary students from FEUP and UTAD institutions. By volunteering to participate and provide contributions, these students belong to the target audience for the game. This approach ensures that all game elements will be tested, including the jellyfish matching mechanic, and that players with an interest in making contributions besides just seeking entertainment from the game are considered. With this emphasis, the following points are specified:

- **Where and When:** The developed game is accessible for the participants to play and conduct the experiment from anywhere. The experiment spans over the course of a week during the month of May.
- **Equipment and Software:** An Android mobile device with an internet connection is required to play the game. It must additionally support the Google Services for AR, which

JellyfishGO! uses for its AR features. Any device with an internet connection and web browser (computer, tablet, or mobile device) can be used for the questionnaire.

- **Coordinator, observer, and facilitator:** The gameplay part of the experiment is conducted without direct control or supervision, due to the impossibility of doing so over the course of a week. This approach also ensures that participants play and spend time on the game naturally, according to their own interest. The questionnaires are conducted individually, where participants have until an announced date to complete them.
- **Participants:** The experiment welcomes as many participants as possible, with the restriction that they are over the age of 18 and possess an Android mobile device compatible with the Google AR Services. Participation is voluntary. Strategies for reaching participants are explained in section 5.3.
- **Assessment Methods:** The primary method involves the collection of internal game data to gauge the level of engagement and retention with each of the game elements. Additionally, there are questionnaires to gather insights into the system's usability and player type according to Bartle's taxonomy, as well as questionnaires regarding the gameplay experience.
- **Help Resources:** A meeting with all participants is held, prior to starting the experiment, to lay out the experiment process and answer any questions the participants may have. This ensures everyone understands and is in line with the experimental procedure. Throughout the week of gameplay, participants may contact coordinators in case of game related issues, but otherwise there is no direct supervision.

5.3 Participant Gathering

Ensuring the gathering of participants with an interest beyond just playing the game for entertainment, but also for contributing to science, is key for obtaining comprehensive and meaningful insights into the effectiveness of the game elements while in the context of a citizen science game.

Participants were gathered mainly through word of mouth, where coordinators invited people from their social circles and around the FEUP and UTAD facilities. Any person that showed interest had to then fill out a form to indicate the institution they were signing up from and their Discord username. The form also included details regarding the experiment processes and restrictions on participation.

The participants that filled out the form were then invited into a Discord server, where the rest of the experiment would take place. When entering the server, their display names were changed to protect and maintain their anonymity.

As another means to motivate potential participants, prizes are offered to the participant with the highest score on the leaderboard, as well as to the members of the highest scoring team. To be eligible to win a prize, a participant is required to have submitted responses for all questionnaires.

5.4 Experiment Procedure

As mentioned in section 5.2, the gameplay part of the experiment is without direct interaction between the participants and the experiment orchestrator, to incentivize a natural and spontaneous gameplay experience.

The questionnaire about the player type is built into the game, and each player fills it out on their first login. The questionnaire about the system usability is given out during the gameplay week, and the questionnaires regarding gameplay experience are handed out for completion after the gameplay week. All the questionnaires, except the player type questionnaire, are announced and delivered in the experiment's Discord server.

The procedure that each participant must undertake is as follows:

1. Participants are invited to a meeting prior to the start of the gameplay part of the experiment. This meeting, coordinated by the experiment orchestrator, has the goal of explaining the overall process of the experiment to all participants, as well as giving them the consent terms regarding the experiment. The meeting is done in a voice channel of the experiment's Discord server.

2. The game application is made available for participants to download and the server's API service is activated. Participants spend a week playing the game. During this time, internal game data is collected in the database for later analysis. Participants may also contact the experiment's orchestrator in case of any game related issues through the experiment's Discord server.

3. In the middle of the gameplay week, the SUS questionnaire is announced and given out for participants to complete.

4. Exactly seven days after the API was activated, it is deactivated, terminating the gameplay week. Participants are then handed out the follow-up questionnaires regarding their gameplay experience.

Further details regarding the questionnaires' structure can be found in section 5.8.2.

5.5 System Load

The game relies roughly equally on client-side and server-side processing. The game's performance depends on the capabilities of the specific device used in the experiment, but certain game elements such as the teams and leaderboards depend on a reliable server connection to synchronize and update data across all game instances. This reliance on server connectivity can lead to a significant impact on system load by a large number of participants, resulting in occasional delays, lag and overall slowness in the gameplay. However, given the expectancy of a small number of participants (≤ 100), the game is unlikely to be affected by unstable server connections due to many clients trying to communicate with the server.

5.6 Completion Criteria

An experiment is complete once the participant acknowledges and accepts the consent form, plays the game throughout the allotted time, and submits answers to all of the questionnaires.

5.7 Success Criteria

For the experiment to be considered successful, it must first and foremost achieve the minimum score in the system usability scale. If, and only if, the system is validated in terms of usability, can the internal game data and questionnaire data be used to extract insights and conclusions.

Additionally, to determine the success of an experiment, the answers to the questionnaires are used in conjunction with the collected internal game data – for example, a participant that answers that they felt a strong feeling of engagement and retention for one or more game elements, their internal game data must show that they spent significant time in the game and interacted with it.

5.8 Assessment Methods

This evaluation aims to measure player experience regarding engagement and retention through the collection of internal game data and gameplay related questionnaires. Moreover, it also aims to validate the system through the SUS, and gather insights into player types via a questionnaire tailored for this task.

The SUS form and gameplay questionnaires were created using Google Forms, while the player type form was created directly inside the game. Internal game data is gathered throughout a player's game session, via communications with the API, to maintain the database player data and local player data synchronized and updated.

To assist in correlating data between these methods, a unique player ID is assigned to each participant at the start of the experiment, and in the questionnaire the participants are required to indicate their player ID.

5.8.1 Informed Consent Form

Prior to start playing, participants are provided with a consent form detailing the goal and purpose of the experiment. They are informed that participation is entirely voluntary, allowing them to withdraw at any point in the study. Participants are assured that the data collected will be used solely for research purposes. Before moving forward, participants are asked to agree to the following terms to consent to participate and provide the necessary information:

- "Do you agree to participate in this experiment, understanding that your responses to questionnaires are registered and analyzed for research purposes?"
- "Do you agree to have your in-game data collected and analyzed for research purposes?"

5.8.2 Formative Questionnaire

The questionnaires provide valuable data, from determining the usability of the system, to complement the collected in-game data, and even to give insights into other areas of research, in this case regarding player types.

Google Forms was chosen as the platform to develop the questionnaires for its user-friendly interface and widespread recognition. In addition, given the game is written in English and participants being university students, English is selected as the language of the questionnaire to ensure consistency without the loss of comprehension among participants.

5.8.2.1 Player Type Questionnaire

The player type questionnaire is a set of questions whose goal is to calculate, based on the answers provided by the participant, the type that the participant fits in according to Bartle's taxonomy. Each answer carries an associated score, related to a specific type, and at the end of the questionnaire the average of the total score of the chosen answers reflects the participant's player type.

Each of the questions presents the player with a hypothetical scenario, and two possible answers that each reflect a specific player type, from which the participant may only choose one. The questionnaire's structure is intentionally built to be able to identify the player type of the participant with the least amount of questions. There are six total questions, thus six scenarios, all required to be completed. They are listed below, alongside the possible answers and the two contrasting types the scenario explores:

- **PTD 1 (Explorer-Achiever):** On a game, a new area opens up. Which do you look forward to more? (+E Explore it / +A Be first to get gear?);
- **PTD 2: (Killer-Achiever):** When playing a video game, is it more fun to: (+A Have the highest score on the list? / +K Beat your best friend one-on-one?);
- **PTD 3 (Killer-Explorer):** Would you rather: (+K Defeat an enemy / +E Explore a new area);
- **PTD 4 (Socializer-Achiever):** Would you rather be: (+S Popular / +A Wealthy);
- **PTD 5 (Socializer-Explorer):** You're a player on a mud, and you want to fight a really tough dragon. How would you approach this problem? (+S Get a big group of players to kill it. / +E Try a variety of weapons and magic against it, until you find its weakness);
- **PTD 6 (Socializer-Killer):** Is it better to be: (+K Feared / +S Loved)

5.8.2.2 SUS Form

The System Usability Scale form aims to glean insights into the ease of use and comprehension of the system by the participant, while also being a way to validate the system. The SUS form

adheres to the standard ten-item attitude Likert scale, offering a comprehensive overview of the subjective usability assessments:

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

For a system to be considered valid according to the SUS test, the average system usability score must be at least 68.

5.8.3 Internal Game Data

Internal game data collection is the method used to provide answers to the research questions. The data is continuously collected during the week where participants play and interact with the game, and saved in the server's database.

Collection strategies involve simple communication between the game application and the API, where the game when triggered by a certain game action, sends updated data to the server.

The aim is to gather as much potentially relevant data (see table 5.1) to gauge the impact on player engagement and retention by each game element, and then during analysis, if necessary, to filter out data that didn't prove to be provide any insight.

Table 5.1: Internal data collected in JellyfishGO!

Game Element	Data Collected
Leaderboards	Player ranking and score, jellyfish captured, leaderboard page visits
Missions	Missions completed, mission page visits
Badges	Badges obtained, badges page visits
Teams	Team score, team jellyfish matches, team page visits

5.9 Limitations

Under the time constraints of this research, only a single experiment is performed to both test the system's usability and provide answers to the research questions. Ideally, there would be a first test to validate the system with the SUS, and then, if the system is validated, a second test to gather data and achieve the other research goals.

External factors may influence participants engagement with the game, and thus influence their collected data. These will be taken into consideration when analyzing and interpreting the results after the experiment takes place.

5.10 Summary

This chapter has detailed the comprehensive experimental protocol designed to evaluate the impact of new gamification elements on player engagement and retention within the JellyfishGO! game. The methodology centers around assessing whether these additions enhance the overall gameplay experience and incentivize continued play, through both questionnaires and collected internal game data.

The experiment addresses key research questions relating to system usability, player engagement, and player typology based on Bartle's taxonomy. Conducted remotely over one week, it targeted voluntary participants from FEUP and UTAD, using their natural gameplay behavior to ensure authentic data collection. To support this, participants were briefed in advance, provided with necessary technical requirements, and offered support channels while maintaining a minimally intrusive observation structure.

A series of carefully designed questionnaires—including a built-in player type assessment, a mid-experiment SUS form, and post-gameplay experience forms—supplemented the internal data collection. All data points were linked via unique participant IDs to enable precise correlation during analysis.

To ensure informed participation, a consent process was implemented, and financial incentives were offered to boost participation rates. While system limitations—such as the reliance on a single round of testing and potential external influences—were acknowledged, mitigation strategies were embedded into the experimental design wherever feasible.

In summary, this protocol provides a solid foundation for evaluating both the usability and effectiveness of gamified features in a citizen science game context, laying the groundwork for informed analysis and future iterations.

Chapter 6

Results & Discussion

6.1 Participant Analysis

The case study performed required the gathering of volunteer participants to playtest the game for the duration of a week and to answer the questionnaires. Participants were not obligated to neither play the game nor to answer any the questionnaires. Table 6.1 presents the number of participants, participation percentage, and dropout percentage for each phase of the study.

Table 6.1: Participants statistics

Study Phase	# of Participants	Participation %	Dropout %
Sign-up	85	100	-
Playtest	53	62	38
Post-questionnaires	29	34	66

We can observe that 62% of participants (53 out of 85) playtested the game, with a 38% dropout. A participant is considered to have playtested the game if they have at least opened the game, logged into their account and completed the in-game player type questionnaire. The dropout in participants during the phase can be attributed to several factors, including:

- **External factors:** It is possible that participants were not able to playtest the game due to external factors, outside of the control of the case study. The study took place during the exam period for many of the participants, which likely influenced their ability to play the game and answer the questionnaires.
- **Compatibility issues:** A known factor to have caused issues with some participants are the compatibility issues. Namely, the game can only be played on an Android mobile device, and the device must also be compatible with the Google AR Services, a service used in the game for its AR features.

Considering all the involved factors which led to the dropout of participants during the playtest phase, achieving a 62% participation rate is quite satisfactory.

In the final phase of the study, the completion of the post-questionnaires, only a total of 29 out of the original 85 participants (34%) submitted an answer. The more significant dropout rate (66%) in this phase can be linked to participants losing interest in the study. The exact reasons for the dropouts isn't known since there was no method to extract that information from the participants, thus the reasoning here is speculative. A possible method could have been to interview individually the participants and ask for the reason of their dropout.

For the effects of the game data analysis and post-questionnaires analysis done in section 6.3 and 6.4 respectively, the data analyzed comes from the 22 participants that scored above the minimum threshold for the System Usability Scale score (above 67).

6.2 Player Type Analysis

As stated in section 6.1, 53 participants playtested the game. Figure 6.1 shows the distribution of the participants that playtested the game according to their player type, determined after completing the in-game player type questionnaire.

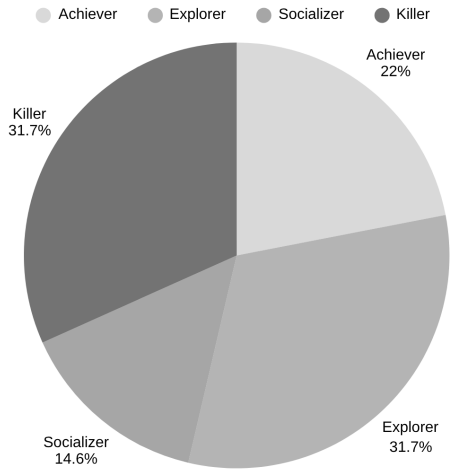


Figure 6.1: Participant player type distribution.

It is of note that the player types shown in fig. 6.1 correspond to single types. Some participants were identified with a combination of types (as the player type questionnaire allows), such as "Explorer-Achiever". These combined types were broken down into their individual types and used for the creation of the pie chart.

While the analysis of player types and its correlation with player interaction with the game falls outside of the scope of this study, we can still make a few observations. JellyfishGO! managed to attract players of all types, with a bigger appeal towards "Killer" and "Explorer" player types. We can infer from this that JellyfishGO! and its game elements and mechanics cater towards a more specific section of the whole player base. In fact, this is further evidenced when looking

at the way the game elements interact with one another. Capturing jellyfish rewards points, completing missions also rewards points, culminating in the leaderboard system that ranks players by their point amount. These elements' design ultimately favors competition, and thus competitive players, such as those of the "Killer" type. On the other hand, although some game elements also promote player cooperation and socialization, such as the teams system, it wasn't as developed and explored, thus falling short to appeal towards players that favor these game aspects, such as those of the "Socializer" type.

6.3 Game Data Analysis

Throughout the week of playtesting, in-game data from the participants was continuously collected and stored in the server's database. The kind of data that was collected is described in section 5.8.3, and essentially serves to analyze a player's engagement and interaction with each of JellyfishGO!'s game elements.

Table 6.2: Game data statistics

Data Type	Max	Min	Average	Standard Deviation
Overall score	216284	1194	47518	76872
Jellyfishes caught	852	5	169	294
Missions completed	24	2	12	9
Team matches	438	7	152	202

There is a very large variation in the data collected, as shown in table 6.2. There were a few participants who invested heavily in the game and played it intensively, but the large majority didn't invest as much time. The factors that positively and negatively influenced a participant's investment in the game are many, such as external factors, the level of interest in the game, financial motivation (the prize offered at the end of the study for the highest scoring player and team). The game suffered initially from some issues which impacted the ability for participant to capture jellyfishes. These problems were solved early in the playtest week, but it could have negatively influenced the participants interest in the game. It is ultimately unknown the exact reasons as participants weren't inquired, so these are speculative factors.

To assist in analyzing a player's engagement and retention with each game element, the number of page visits a participant made for each element was also collected. For example, every time the participant opened the mission's page in the game, the counter for mission page visits of that participant would increment. The same was done for the teams and leaderboard pages for every participant. Table 6.3 displays the statistics regarding page visits for each of the game elements.

Table 6.3: Page visits statistics

Data Type	Max	Min	Average	Standard Deviation
Missions page visits	111	2	17	26
Leaderboard page visits	236	0	17	55
Team page visits	100	3	18	24

Similar to the game data statistics, the page visits also suffer from significant variations. This can be better visualized in the graphs shown in figures 6.2, 6.3, 6.4.

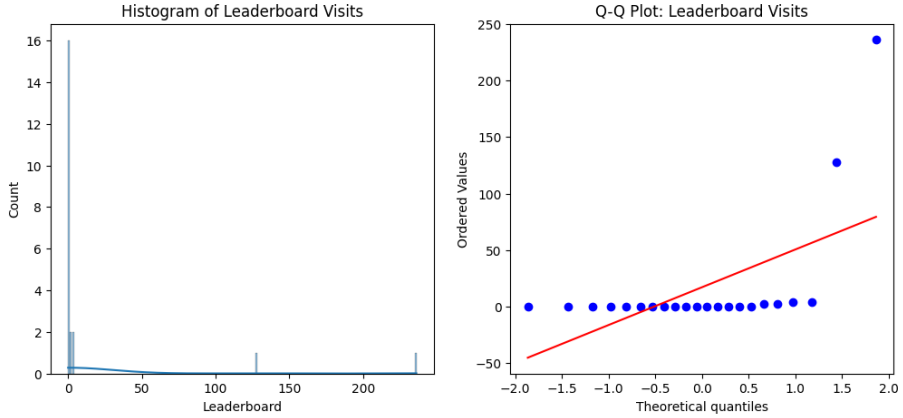


Figure 6.2: Leaderboard page visits dat distribution.

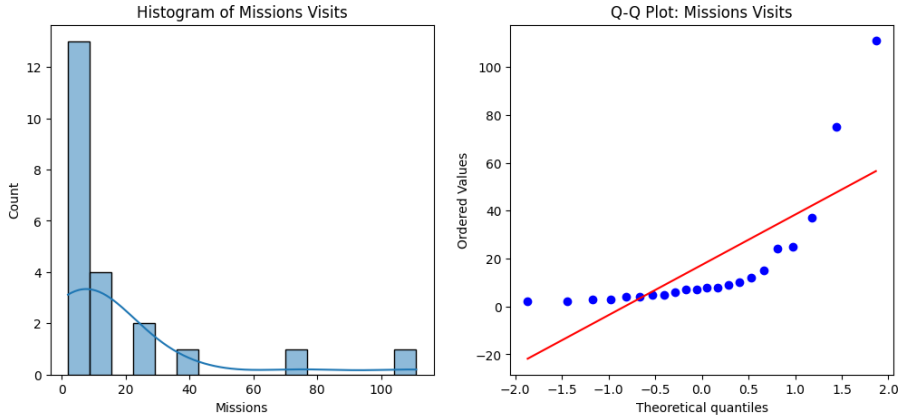


Figure 6.3: Mission page visits data distribution.

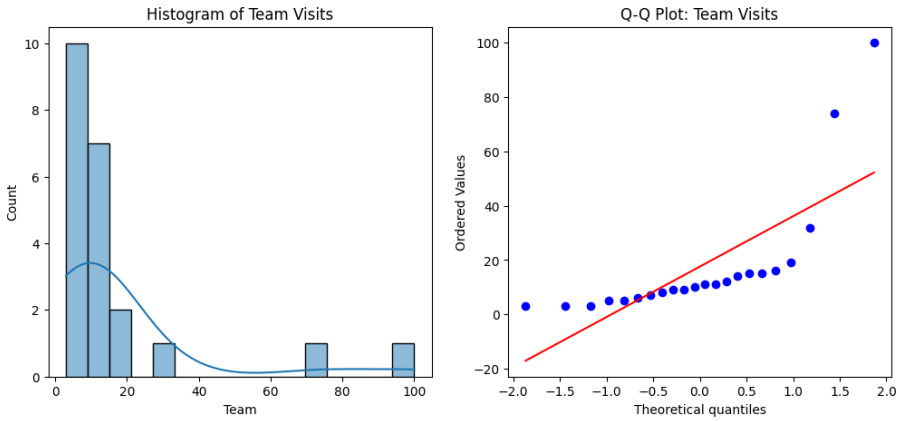


Figure 6.4: Team page visits data distribution.

None of the distributions resemble a normal distribution. The departure from normality is further exacerbated when taking into account the p-value of the Shapiro-Walk test, which is exactly 0 across all of the datasets. Similar behavior can be observed in the game data shown in table 6.2. This significant deviation from normality of the collected game data makes it statistically unstable and thus inconsistent. Therefore, we are unable to make any meaningful observations from it alone, and it's difficult to accurately correlate it with other data, such as from the post-questionnaires. In order to provide insights and answers to the research questions, we will rely on the more consistent and stable data from the post-questionnaires.

6.4 Post-Questionnaires Analysis

6.4.1 System Usability Scale (SUS)

In order to evaluate the overall usability of the JellyfishGO! GWAP (Game With A Purpose), it is crucial to submit the players to a usability scale questionnaire to verify the ease of use and satisfaction with our GWAP. To serve this purpose, we used the System Usability Scale presented by John Brooke [8], a questionnaire that stands out for its versatility and robustness in capturing user perceptions regarding software and hardware systems.

Table 6.4: System Usability Scale statistics

Score and Interpretation	Value
SUS Study Score	73.75
Median	75
Standard Deviation	11.5
Adjective Scale	Good
Grade Scale	B
Acceptability	Acceptable

According to John Brooke in [8], systems with scores above 68 are considered to be above average. As we can see in the Table, we obtained a SUS score of 73.75, which means that the JellyfishGO! GWAP was reasonably well received by players in terms of ease of use and satisfaction. This validates that the game's interface and mechanics are intuitive, contributing positively to the overall user experience. The fact that we obatain a median of 75 also supports the idea that, in general, the game reached good levels of acceptance for the players. It is also important to mention that we obtained a standard deviation of 11.5. Although a lower standard deviation would be preferred, the value we obtained denotes a certain variability in user opinions about the usability of the game. The fact that the game is only available for Android users, and that not all Android devices share the same characteristics and capabilities, such as Augmented Reality availability (that is only available on ARCore compatible devices and a crucial characteristic to play JellyfishGO!), might explain the variability in user satisfaction.

We also used the evaluated the usability of our GWAP with three more scales, the Adjective Scale [34], the Grade Scale [35] and the Acceptability scale [4], which also allows for complementary analyses on the GWAP quality, and help us to understand the perception of players.

The adjective scale contextualizes SUS study scores on descriptive adjectives ranging from "Worst Imaginable" to "Best Imaginable". It is based on [34] interpretation of the primary data by Bangor et al. [3] . JellyfishGO! obtained the descriptor "Good" in this scale which reinforced that JellyfishGO! has an overall efficient usability and ease of use. The Grade Scale uses letter grades (from "F" to "A") to understand the absolute meaning of a SUS score, which can also provide complementary insights on the usability of our GWAP. It is based on the data from [34]. JellyfishGO! obtained a letter grade B, which is consistent with the previous results, and reinforces the idea that JellyfishGO! has a positive usability. The Acceptability Range offers another complementary analysis, classifying the usability of the system based on score ranges. It contextualizes SUS study scores on descriptions ranging from "Not Acceptable" over "Marginally acceptable" to "Acceptable". This scale is based on data from Bangor et al. [4] and derived from implications of the grading and adjective scales. JellyfishGO! was classified as "Acceptable", which again follows the trend from the other scales.

6.4.2 Gaming Motivation Scale (GAMS)

In order to explore how JellyfishGO! and other citizen science games with a competitive and cooperative nature, can stimulate players motivations, we presented the participants with the Gaming Motivation Scale (GAMS) [17], a 18-item questionnaire that measures six types of motivation: Intrinsic Motivation (which refers to the enjoyment and interest derived from the game), Identified Regulation (which reflects a conscious valuing of the activity), Introjected Regulation (performing an activity to avoid negative feelings like guilt or shame), External Regulation (performing an activity to obtain rewards or avoid punishments), and Amotivation (or lack of motivation). Each sub-scale score was calculated as the average of its three constituent items, rated on a 7-point Likert scale.

Table 6.5: Gaming Motivation Scale statistics

Sub-scale	Mean	Standard Deviation	Max	Min
Intrinsic Motivation	14.81	4.50	21	6
Integrated Regulation	12.85	3.78	21	6
Identified Regulation	13.31	3.44	20	6
Introjected Regulation	9.54	4.79	19	3
External Regulation	11.71	4.28	19	5
Amotivation	7.46	4.45	21	3

Table 6.5 presents the descriptive statistics of the Gaming Motivation Scale results for each subscale. These statistics show that Intrinsic Motivation was the most prominent regulation (M=14.81, SD=4.50), followed by Identified Regulation (M=13.31, SD=3.44) and Integrated Regulation (M=12.85, SD=3.78). These three subscales indicate that most players engage with JellyfishGO! because they find it enjoyable, personally meaningful, and aligned with their values. External Regulation (M=11.71, SD=4.28) was moderately high, suggesting some players are driven by rewards such as points or leaderboard status. Introjected Regulation (M=9.54, SD=0.79) and Amotivation (M=7.46, SD=4.45) were the lowest, indicating that guilt-based or purposeless motivation is generally low in the sample.

Table 6.6: Gaming Motivation Scale Shapiro-Wilk normality test

Sub-scale	W	p-value	Deviates from normality	Cronbach's alpha
Intrinsic Motivation	0.939	0.106	No	0.95
Integrated Regulation	0.980	0.845	No	0.86
Identified Regulation	0.948	0.174	No	0.75
Introjected Regulation	0.929	0.059	No	0.86
External Regulation	0.939	0.103	No	0.68
Amotivation	0.003	0.003	Yes	0.87

Table 6.6 presents the results of the Shapiro-Wilk normality test for each subscale. confirmed that all subscales except Amotivation followed normal distributions (p>.05), with Amotivation showing a significant deviation (W=0.871, p=0.003). Reliability was strong for all subscales except External Regulation, which had a slightly lower Cronbach's alpha (α=0.68), while the others ranged from acceptable to excellent (α=0.75–0.95). Consequently, we conducted a Friedman test, a non-parametric tests were adopted to avoid making assumptions of normality and enhance the robustness of the analysis. The Friedman test revealed significant differences across the six motivational regulations (χ^2=36.67, p<0.001), with a Kendall's W of 0.262, indicating a moderate effect size.

Table 6.7: GAMS subscales comparison

Comparison	p-raw	p-adjusted	Significant
Intrinsic Motivation vs. Integrated Regulation	0.02075	0.311252	No
Intrinsic Motivation vs. Identified Regulation	0.023358	0.350366	No
Intrinsic Motivation vs. Introjected Regulation	0.000749	0.011242	Yes
Intrinsic Motivation vs. External Regulation	0.00641	0.096143	No
Intrinsic Motivation vs. Amotivation	0.001568	0.001568	Yes
Integrated Regulation vs. Identified Regulation	0.47089	1	No
Integrated Regulation vs. Introjected Regulation	0.001607	0.024099	Yes
Integrated Regulation vs. External Regulation	0.405824	1	No
Integrated Regulation vs. Amotivation	0.000353	0.005302	Yes
Identified Regulation vs. Introjected Regulation	0.000689	0.010337	Yes
Identified Regulation vs. External Regulation	0.099232	1	No
Identified Regulation vs. Amotivation	0.004314	0.004314	Yes
Introjected Regulation vs. External Regulation	0.016208	0.24312	No
Introjected Regulation vs. Amotivation	0.080735	1	No
External Regulation vs. Amotivation	0.002594	0.03891	Yes

Post hoc analysis using Wilcoxon signed-rank tests with Bonferroni correction, presented in Table 6.7, showed that Intrinsic, Identified, and Integrated Regulation scores were each significantly higher than Amotivation and Introjected Regulation. Intrinsic Motivation was also significantly higher than Introjected Regulation. External Regulation scored significantly higher than Amotivation, but did not significantly differ from the top three internal motivations.

The results from the GAMS motivations and the Friedman post-hoc analysis provided valuable information on how to stimulate motivation among all players in a gamified competitive and cooperative citizen science games, like JellyfishGO!. In these scenarios design strategies must prioritize and support the dominant motivational profiles within the player base — that is, Intrinsic, Identified, and Integrated motivations. Players driven by Intrinsic Motivation—the highest-rated motivational factor in our research — promoted pleasure and interest from inherently enjoyable gameplay. Consequently, JellyfishGO! and other competitive and cooperative GWAPs should focus on maintaining a gameplay environment that is inherently fun and engaging by incorporating playful visuals, satisfying interactions, varied missions, and rich sensory feedback.

In line with this, players who exhibit Identified and Integrated Regulation perceive personal value and alignment with their own goals or identity, which means the game should clearly communicate its underlying real-world scientific purpose (for example, “With your jellyfish sightings you are giving a valuable contribution to science”), offer personalization options, and weave narrative or thematic elements that resonate with the players’ sense of self. Although External Regulation — characterized by elements such as points, badges, and leaderboards — plays a moderate role, these elements should serve to complement the intrinsic fun or personal significance of

the experience, particularly for goal-oriented players. Lastly, forms of motivation such as Introjected Regulation and Amotivation were low and generally undesirable, implying that the design should avoid inducing guilt or a sense of purposelessness. To mitigate amotivation, onboarding and feedback processes should be clear, with the players' contributions made visible and purposeful through progress indicators or reminders of impact; gentle social nudges or cooperative cues, like highlighting teammate contributions, can further activate constructive, yet pressure-free, introjected motivation.

6.4.3 Player Experience of Need Satisfaction (PENS)

To complement the GAMS analysis and to better understand the qualitative experiences of the participants and what motivates them to engage in competitive-cooperative citizen science games like JellyfishGO!, we administered the 9-item Player Experience of Need Satisfaction (PENS) questionnaire [33] immediately after players' JellyfishGO! sessions. This instrument assessed the degree to which JellyfishGO! supported players' psychological needs for autonomy, competence, and relatedness. Just like in the GAMS, each sub-scale score was calculated as the average of its three constituent items, rated on a 7-point Likert scale.

Table 6.8: PENS statistics

Sub-scale	**Mean**	**Standard Deviation**	**Max**	**Min**
Autonomy	14.09	4.17	20	6
Competence	14.39	4.73	21	3
Relatedness	13.65	4.88	21	3

Table 6.8 shows the descritive statistics for autonomy, competence, and relatedness scores. Descriptive results showed that Competence was rated highest (M=14.39, SD=4.73; range 3–21), closely followed by Autonomy (M=14.09, SD=4.17; range 6–20) and Relatedness (M=13.65, SD=4.88; range 3–21). We also conducted Shapiro-Wilk tests to verify if all the subscales are normally distributed.

Table 6.9: PENS Shapiro-Wilk normality test

Sub-scale	**W**	**p-value**	**Deviates from normality**	**Cronbach's alpha**
Autonomy	0.924	0.081	No	0.87
Competence	0.926	0.089	No	0.93
Relatedness	0.953	0.335	No	0.88

Table 6.10: PENS subscales comparison

Comparison	p-raw	p-adjusted	Significant
Autonomy vs Competence	0.653904	1	No
Autonomy vs Relatedness	0.605152	1	No
Competence vs Relatedness	0.291281	0.873842	No

The results of the Shapiro-Wilk tests, presented in Table 6.9, confirmed all three distributions were approximately normal (all p > .05). Cronbach's α indicated strong reliability for each subscale (Autonomy = 0.87; Competence = 0.93; Relatedness = 0.88). Therefore, a repeated measures ANOVA was performed to test for any significant differences between the three subscales. The repeated-measures ANOVA revealed no significant differences among the needs —F(2,42)=0.55, p=0.58 — indicating that players felt their needs for autonomy, competence, and relatedness were satisfied to similar extents. Consistent with this, Bonferroni-corrected paired t-tests, presented in Table 6.10 found no significant contrasts (all $p_{adj} > 0.29$).

The findings from PENS, alongside the GAMS results, demonstrate that JellyfishGO! and competitve-cooperative citizen science games not only tap into strong intrinsic and identified motivations but also fulfills players' core needs for autonomy, competence, and relatedness. Autonomy is supported by allowing players the freedom to choose which missions to tackle each session, while competence is built through clear, immediate feedback via the individual leaderboard and mission point tallies, reinforcing the sense of mastery as players catch jellyfish and complete tasks. Social bonds are enhanced by fostering relatedness through team leaderboards and cooperative "match" bonuses awarded when partners catch the same jellyfish, thereby creating a shared sense of achievement.

To further motivate players through citizen science GWAPs, these competitve and cooperative games should enhance mission variety and autonomy by introducing branching mission paths, such as timed challenges, thematic quests, or optional side-objectives. This would enable players to pursue personal goals without feeling constrained by a linear gameplay structure. Additionally, reinforcing competence with adaptive feedback—by augmenting the individual leaderboard with personalized progress bars or milestone badges, and including in-game prompts that highlight successful catches—can further sustain players' mastery feelings. Deepening team engagement could involve expanding the team leaderboard to visualize cumulative team streaks or unlocking group missions that require coordinated effort, with "match" achievements showcased in a shared feed to amplify social connection. Finally, balancing external rewards with intrinsic fun is crucial; while leaderboards drive competence, playful UI animations, celebratory effects, and a narrative emphasizing the science-game purpose ensure that players experience both the joy of discovery and the thrill of competition.

This integrated, element-focused strategy—optimizing leaderboards, missions, and teamwork simultaneously— stimulate players' strongest motivations and ensures balanced need satisfaction, thereby maximizing engagement and contribution across the JellyfishGO! community.

6.4.4 Element Impact Questionnaire (EIQ)

The 12-item Element Impact Questionnaire was designed to directly measure the perceived influence of specific game elements—leaderboards (individual and team), missions, and team dynamics (through matches)—on player motivation. This questionnaire was developed based on the Intrinsic Motivation Inventory (IMI) by Ryan and co-authors [32]. Like the GAMS and PENS questionnaires, this one was also presented immediately after each play session and relied on 7-point likert scales.

Table 6.11: EIQ statistics

Sub-scale	Mean	Standard Deviation	Max	Min
Individual Leaderboard	16.69	3.57	21	9
Team Leaderboard	15.43	4.64	21	7
Missions	15.74	4.22	21	6
Team Dynamics (Matches)	14.91	4.83	21	4

Descriptive statistics for the EIQ questionnaire, presented in Table 6.11, showed that the Individual Leaderboard scored highest in impact (M=16.69, SD=3.57; range 9–21), followed by Missions (M=15.74, SD=4.22; range 6–21), Team Leaderboard (M=15.43, SD=4.64; 7–21), and Match Bonus (Team Dynamics) last (M=14.91, SD=4.83; 4–21). We also conducted Shapiro-Wilk tests to verify if all the subscales are normally distributed.

Table 6.12: EIQ Shapiro-Wilk normality test

Sub-scale	W	p-value	Deviates from normality	Cronbach's alpha
Individual Leaderboard	0.919	0.064	No	0.81
Team Leaderboard	0.913	0.046	Yes	0.91
Missions	0.918	0.059	No	0.90
Team Dynamics (Matches)	0.922	0.074	No	0.94

The results of the Shapiro-Wilk tests presented in Table 6.12, indicated that only the Team Leaderboard subscale deviated from normality (W=.913, p=.046), while the others were approximately normal (p>.05). Cronbach's α demonstrated good to excellent reliability: Individual Leaderboard = .81; Team Leaderboard = .91; Missions = .90; Match Bonus = .94. Consequently, similar to the procedure used with the GAMS results, we performed a non-parametric Friedman test to test for statistically significant differences between each group. The Friedman test found no statistically significant differences across the four elements—$\chi^2(3)=5.37$, p=.147—with a small effect size (Kendall's W = .078). Post-hoc Wilcoxon comparisons (Bonferroni-adjusted $\alpha \approx .0083$), presented in Table 9, revealed no significant pairwise contrasts (all adjusted p > .05), though raw p-values hinted at higher ratings for Individual Leaderboard over Team Leaderboard (p=.037) and over Match Bonus (p=.017).

The findings from the EIQ questionnaire revealed that all four game elements used in JellyfishGO! were rated positively, but the Individual Leaderboard emerged as the most enjoyable, motivating, and engagement-driving feature, with Missions following closely behind. Team-based mechanics—namely the Team Leaderboard and Match Bonus—scored slightly lower, suggesting that while cooperation and social competition are valued, they do not carry the same universal appeal as individual achievement and structured challenges. When integrated with our GAMS and PENS findings, which show that intrinsic enjoyment, competence, and balanced need satisfaction drive engagement, these EIQ results offer clear recommendations for competitive and cooperative nature GWAPs aiming to optimize citizen science for all players. It is advisable to prioritize individual leaderboards by making personal performance feedback highly visible through dynamic ranking, milestone badges, and real-time stats, thereby sustaining motivation and competence. Additionally, enhancing mission variety by offering diverse, thematically rich missions with clear objectives and rewards taps into intrinsic interest and provides meaningful challenges. Although team leaderboards should be maintained to support social relatedness, they must be streamlined for easy interpretation and occasionally include shared goals to boost cooperative pull. Furthermore, match bonuses should be used sparingly as occasional surprises or event-based mechanics rather than as core play drivers, ensuring that social features do not feel obligatory.

6.5 Summary

This chapter presented a comprehensive analysis of the results obtained from the case study of the JellyfishGO! game. It began with a review of participant engagement, revealing moderate drop-off rates between the sign-up, playtesting, and post-questionnaire phases, with key issues attributed to external factors and device compatibility. Despite these challenges, 62% of participants playtested the game, and 34% completed the post-questionnaires, allowing for a meaningful analysis.

The player type analysis indicated that JellyfishGO! attracted a wide range of player archetypes, with a notable appeal to "Killer" and "Explorer" types. Collected game data revealed a high degree of variance and statistical instability, limiting its interpretability and necessitating a focus on the more stable post-questionnaires results.

Usability was evaluated using the System Usability Scale (SUS), with JellyfishGO! scoring 73.75, indicating good usability and player satisfaction. Additional scales (Adjective, Grade, Acceptability) corroborated this positive reception.

Player motivation was examined using the Gaming Motivation Scale (GAMS), which highlighted strong intrinsic and identified motivations among participants. Statistical analysis further confirmed significant differences between motivational subscales, reinforcing the importance of designing gameplay that emphasizes personal enjoyment and meaning.

The Player Experience of Need Satisfaction (PENS) questionnaire showed that JellyfishGO! effectively supported players' psychological needs for autonomy, competence, and relatedness. While no significant differences were found among these needs, the game's design was successful in addressing them equally.

Finally, the Element Impact Questionnaire (EIQ) provided insights into which game features most influenced motivation. The individual leaderboard emerged as the most impactful, followed by missions, while team-based elements were rated slightly lower, suggesting a preference for individually oriented challenges.

Overall, the chapter demonstrated that JellyfishGO! was well-received in terms of usability, successfully fostered intrinsic motivation, and met core psychological needs through its game elements. These findings offer valuable design implications for future development of competitive and cooperative citizen science games.

Chapter 7

Conclusions

7.1 Research Questions

The main goal of this research was to study the role that game elements have on player engagement, retention and contribution in citizen science games. To achieve this, we formulated the research questions in section 1.4, then designed and performed the case study (5), and finally analyzed the results obtained from the study (chapter 6) to provide answers to the research questions. The research questions and their answers are as follows:

RQ1: *"Which gamification strategies are the most impactful in terms of player engagement and retention?"*

With this question, we wanted to assess the impact the game elements had on player engagement and retention specifically, and also to see which element proved to be the most impactful in this regard.

Based on the post-questionnaire data, particularly the EIQ questionnaire results (section 6.4.4), we were able to identify that the individual leaderboard was rated as the most engaging by the players, followed by the mission system, with the team based elements at the bottom. We can thus conclude that the competitive aspect of the game proved more effective in player engagement than the cooperative aspect. This can, however, also be attributed to the player type distribution of the participants that playtested JellyfishGO!, where there was a prevalence of competitive players over cooperative ones (section 6.2).

Regardless of the individual role that each game element had on player engagement and retention, it is also important to recognize the collective role of all game elements and their interactions together. Despite the inconsistencies in the collected game data (section 6.3), one observable trend was that the players who scored the highest, were also the players who caught the most jellyfish, completed the most missions, and even made the most team matches.

RQ2: *"What is the effect of the introduction of gamification strategies on player contribution in a citizen science project?"*

The purpose of this research question is to evaluate the impact that gamification strategies have on player contribution. This is specially important as the success of citizen sciences games sits on

the contributions of their playerbase. Ideally, gamification strategies should incentivize players to contribute, and thus positively impact player contribution.

While the case study performed in this research didn't directly address this question, the collected data gives us insights that we can use to provide an answer. As stated earlier, we observed that the players who engaged and interacted the most with the game elements, are also the players who made the most contributions by capturing the most number of jellyfishes. Therefore, we can accurately conclude that the introduction of gamification strategies, in the form of the new game elements, to JellyfishGO! lead to a positive effect on player contribution. However, an experiment that would tackle this question more specifically could provide a more precise answer to this question. An example of such experiment is to provide a portion of the participants with a version of the game without the gamification strategies implemented and the other portion a gamified version, then compare and analyze the contribution of participants from each portion. For this research, due to time constraints it was not possible to include this experiment in the case study.

7.2 Outcomes

This research project contributed to the area of *Citizen Science*, namely in the *Gamification in Citizen Science Projects*. From this work, we identified three main outcomes: ***(i)*** an extensive literature review on the main concepts of our project, ***(ii)*** the development of a gamified version of JellyfishGO! with a rich gameplay foundation, and ***(iii)*** an empirical experiment (the case study) the scientific community and future iterations of the JellyfishGO! development can replicate.

7.2.1 Literature Review

To understand what kind of projects already exist on the main topics of our research, we performed an extensive and comprehensive evaluation of the existing state-of-the-art (chapter 2 and 3). With it, we aimed to identify, analyze, and summarize relevant projects, approaches, and concepts like other citizen science games, player motivations, cognitive theories behind gamification strategies, and gamification strategies themselves.

Through it, we could evaluate the strengths, weaknesses, and gaps of several approaches, identifying the key challenges of our main topics and areas where we could go further in our study. By analyzing the state-of-the-art, we were also able to provide a foundation for future research opportunities for ourselves and other researchers.

This literature review allowed us to identify what gamification strategies to implement into JellyfishGO! that make the most out of a player's intrinsic and extrinsic motivations. With it, we were able to study their impact on player engagement, retention and contribution.

7.2.2 JellyfishGO! Game

As mentioned in chapter 1 (sec. 1.1), the Illiad consortium aims to expand their jellyfish forecasting system project into the southern european seas. It relies on initiatives grounded in citizen

science to accomplish this goal.

Thus, another outcome of this research is the game of JellyfishGO!. Albeit still in an early stage, the development iteration performed in this study created a core gameplay loop for the game that future iterations can further enchance and build upon. The game elements introduced in this iteration can become the building blocks for new elements to sit on: the teams system can be refined to have more team based mechanics; the missions system enhanced with more varied reward and mission types.

The ultimate goal with JellyfishGO! is to lead player to the coastal beaches and to contribute to the development of the forecasting system by taking pictures of live jellyfish. This iteration was a significant step towards that goal.

7.2.3 Empirical Experiment

Empirical experiments are a direct result of a research project. They are usually conducted to validate the proposed solution or approach to a particular problem. The results of these experiments provide evidence to support the claims made in the thesis and demonstrate the feasibility and effectiveness of the proposed solution [1, 28].

Besides, the experiments conducted during a project may also contribute to advancing knowledge in the field of study. By gathering and analyzing data, researchers can gain new insights, leading to new discoveries or recommendations for future investigation [1, 28].

Therefore, another outcome from this project is the case study that was carried out (chapter 5). This was an experiment with a reasonable number of participants, that provided us with data to answer our research questions and gather insights into future developments of the game.

Even though the results were satisfactory, there were issues that impacted the overall quality of the study, such as the dropout rates, the compatibility problems and external factors, and the fact that only one iteration of the experiment could be performed.

7.3 Future Work

Even though we feel pretty confident with the work carried out, we know that there are still some points related to our main contributions that could have been further explored. Next, we list some of those issues and how they can be addressed in future research.

While we attempted to cover some of the gaps in the literature (chapter 2, sec. 2.8), such as a long-term study on player engagement and motivation, and to provide a more individual evaluation of game elements on these aspects, there are still gaps that were not addressed here but can prove fruitful to explore in the future development of JellyfishGO!, namely the exploration of funding models.

There is still a lot of room for improvement and enhancement in JellyfishGO!. Not all of the objectives for this iteration of its development were met: the badge system was not implemented, the leaderboards lack a ranking system that also was not implemented. Beyond what remained to

be included in this iteration, future iterations can further refine the game elements and mechanics and add new ones. Also of note is to improve the compatibility of the game with mobile devices, which proved to be a large constraint during the experiment carried out in this research.

Finally, the case study and the experiment protocol can and should be improved in future developments of JellyfishGO!. In particular, to design several iterations of testing and experimentation as part of the study, where the system is continuously validated in each of the iterations. This will allow for better control over what aspects of the development to focus on, as well as optimizing resource management during development. In this study, due to time constraints, we were only able to perform one iteration of testing, which lead to problems being found with the game that ultimately impacted the data that was collected. This could have been mitigated if there were multiple iterations, allowing for the problem to be found earlier and avoiding it conflicting with collected data.

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