Gamified Networked Learning Environments in Higher Education: A Study on Student Engagement and Value Creation in Computer Science

Ali Soleymani[1], Taico Aerts[2], Maarten De Laat[3] and Marcus Specht[1]
[1]Centre for Education and Learning, EWI, TU Delft, Delft, the Netherlands
[2]Computer Science and Engineering Teaching Team, EWI, TU Delft, Delft, the Netherlands
[3]Centre for Change and Complexity in Learning, University of South Australia, Adelaide, Australia

a.soleymani@tudelft.nl
t.v.aerts@tudelft.nl
maarten.delaat@us.as
m.m.specht@tudelft.nl

Abstract: In the rapidly evolving domain of computer science education, fostering deep engagement and sustained motivation among students remains a challenge. This study introduces the Answers platform, a pioneering online learning environment developed at TU Delft. This research aims to reimagine the learning experience for Bachelor and Master of Science Students in computer science by integrating gamification elements grounded in Wenger's value creation framework. Our paper explores two critical research questions: the perception of learners towards gamified learning experiences and the impact of the Answers' system on value creation and motivation. We incorporated points, badges, and leaderboards in a semester-long intervention to enrich the learning landscape. The Value Creation Questionnaire (VCQ) results indicated that the platform effectively created potential and applied value, significantly enhancing students' learning practices and motivation. However, its impact on fostering social connections could have been more pronounced. The platform also moderately influenced students' ability to impact their world and shift perspectives. The Intrinsic Motivation Inventory (IMI) revealed that students generally enjoyed using the platform but felt it did not significantly enhance feelings of connectedness. This paper contributes to the body of knowledge by demonstrating the efficacy of gamification in computer science education and offering insights into the design of engaging online learning platforms. By bridging theoretical frameworks with practical application, the Answers platform exemplifies the potential of gamified environments to revolutionize educational practices in the digital age.

Keywords: Networked Learning, Gamification, Value Creation, Computer Science Education, Online

1. Introduction

1.1 Background and Context

The digital revolution has profoundly transformed educational paradigms, particularly within computer science education, where the rapid evolution of technologies demands innovative pedagogical approaches. Amidst this transformation, gamification is a potent strategy to enhance learning experiences by incorporating game design elements into non-game contexts. This study introduces "Answers," a novel online learning platform developed at TU Delft, aimed at redefining the educational landscape for computer science students. Answers integrate gamification elements within a framework inspired by Wenger's theory of value creation (Wenger et al., 2011). This integration seeks to engage students and deepen their learning and professional development through a networked learning environment.

1.2 Literature Review

Gamification can significantly enhance student motivation and engagement in online education environments. Recent research has consistently shown that incorporating gamification elements into online learning systems positively affects students' participation and learning outcomes. Gamified learning environments effectively engage students using intrinsic and extrinsic motivators, leading to higher motivation levels and improved academic performance (Buckley & Doyle, 2016; Schöbel et al., 2019). Furthermore, empirical evidence supports the notion that gamification strategies can lead to a more stimulating and engaging learning experience, fostering both engagement and problem-solving capabilities among students (García-López et al., 2023; Çağlar et al., 2020).

In computer science education, gamification has shown promise in enhancing student engagement and learning outcomes. Studies have demonstrated that gamified CS courses can increase student motivation, higher retention rates, and improved assessment performance (Dichev & Dicheva, 2017; Barata et al., 2013).

Gamification elements such as leaderboards, badges, and point systems have been found to create a competitive yet collaborative environment that encourages students to actively participate and engage with the course material (Faghihi et al., 2014; López-Fernández et al., 2023). Recent reviews highlight that specific game elements, such as leaderboards and badges, are particularly effective in increasing participation and enhancing the learning experience. However, the impact varies depending on the curriculum's design and integration of gamification elements (Zhan et al., 2022). In line with these findings, Videnovik et al. (2023) review also finds that game-based learning in computer science education can enhance understanding and retention of material, particularly when aligned with curricular goals. The effectiveness is mediated by factors such as game design, integration into the curriculum, and student demographics.

Moreover, the application of gamification in higher education, in general, has highlighted its potential to transform traditional learning environments. By integrating game mechanics into university courses, educators can create more interactive and immersive learning experiences that cater to diverse learning styles and preferences (Huang & Soman, 2013). However, challenges such as ensuring the relevance of gamification elements, impact on learning outcomes, and maintaining student motivation throughout the course remain areas for further exploration (de-Marcos et al., 2014; Zahedi et al., 2019).

In sum, gamification is not merely a trend; it is a robust educational strategy that can significantly enhance the academic experience, especially for the computer science student, by increasing their motivation and engagement in online learning settings.

We utilize the Value Creation Framework introduced by Wenger, Trayner, and De Laat (2011) to assess and articulate the value generated through learning activities in communities of practice. This framework categorizes value creation into five cycles—immediate, potential, applied, realized, and transformative value—each illustrating a different impact that community participation can have on an individual or group (Dingyloudi & Strijbos, 2015). This approach is particularly effective in educational settings where learning outcomes are measured through traditional academic performance and the broader development of skills and capabilities vital in today's interconnected world.

In networked learning, gamification is increasingly recognized as a powerful tool for enhancing professional development. Educators and trainers can significantly boost engagement and motivation among learners by incorporating game-like elements into networked learning environments. This approach has been particularly effective in teacher professional development, where gamification strategies increase participation and encourage applying new knowledge and skills in educators' daily practices (Pozzi et al., 2016). Furthermore, studies have shown that gamification can enrich the learning experience by fostering a student-centered environment, which is crucial for effective professional development in various educational settings (Tsay et al., 2018). The strategic integration of social networks with gamification elements further enhances this impact, creating a more connected learning experience and promoting continuous professional growth.

1.3 Research Gap

The motivation behind this research stems from the observed need for more engaging and effective educational tools that can address the unique challenges of computer science education. Traditional learning platforms often need to improve in fostering motivation and deep engagement, which are critical components for mastering the complex concepts inherent in computer science. In response, our study explores the potential of gamification to fill this gap, hypothesizing that a learning environment enriched with gamification elements can significantly enhance students' learning experience, outcomes, and value creation.

1.4 Research Questions and Objectives

Two pivotal research questions guide our investigation: How do learners perceive the gamified learning experience in computer science Bachelor and Master of Science courses? Does using the Answers system impact the value created and motivation for a course topic? Moreover, how do gamification elements within the platform enhance motivation?

1.5 Significance of the Study

By delving into these questions, this paper aims to contribute to the growing knowledge of gamification in education, offering insights into its application within computer science learning environments. The subsequent sections will detail the methodology adopted for this study, present our findings, and discuss the implications of

integrating gamification with Wenger's value-creation framework in educational settings. Through this exploration, the Answers platform is posited as an innovative model for enhancing engagement, motivation, and learning outcomes in computer science education.

2. Methodology

2.1 Participants

This study engaged 372 participants, including Bachelor and Master of Computer Science students and course instructors actively involved with the Answers-EWI platform throughout the period under analysis.

2.2 Data Collection Methods

To comprehensively assess the impact of the "Answers" platform on learning outcomes and motivation, our study utilized a combination of automatic log data and questionnaires, each tailored to capture different dimensions of the learning experience and value creation.

Log Data: The platform automatically generates log data capturing detailed information on user interactions. This included data on the frequency and type of activities such as question posting, answering, and commenting. Log data provided quantitative metrics on engagement levels, enabling an analysis of how actively and in what ways students and instructors used the platform.

Questionnaires: Two types of questionnaires were administered to participants to gather data on perceived value creation and intrinsic motivation:

Value Creation Questionnaire: Based on Wenger's (2011) five cycles of value creation, this questionnaire was designed to measure the different layers of value participants perceived as being created through their interaction with the platform. The questionnaire items corresponded to the immediate, potential, applied, realized, and reframing value.

Intrinsic Motivation Inventory (IMI) - 29-item Version: This comprehensive tool assessed participants' levels of intrinsic motivation concerning their platform use. It includes five subscales: relatedness, interest/enjoyment, perceived choice, pressure/tension, and effort. The IMI helped us to understand the motivational dynamics influenced by gamified elements of the platform.

Each data collection method was chosen to complement the others, providing a rich, multi-faceted view of the educational impact of the "Answers" platform. Together, these methods enabled a robust analysis of both the measurable outcomes of gamification and the qualitative experiences of those engaged with the platform.

2.3 Research Design

This study employed a mixed-methods research design to evaluate the impact of gamification elements on value creation and student motivation within the Answers platform, a newly developed educational tool for computer science students at TU Delft. The primary objective was to assess how integrating gamification elements such as points, badges, and leaderboards influences students' engagement, learning practices, and intrinsic motivation.

Quantitative data were collected using two key instruments: the Value Creation Questionnaire (VCQ) and the Intrinsic Motivation Inventory (IMI). The VCQ, based on Wenger's (2011) five cycles of value creation, was designed to measure the different layers of value that participants perceived as being created through their interaction with the platform. The IMI assessed participants' levels of intrinsic motivation, focusing on five subscales: relatedness, interest/enjoyment, perceived choice, pressure/tension, and effort.

In addition to the quantitative measures, the VCQ included five open-ended questions to gather qualitative data on participants' experiences. These open-ended responses provided more profound insights into how students perceived the value created by the platform, allowing for a more comprehensive understanding of their experiences.

By combining quantitative and qualitative data, this mixed-methods approach enabled a robust analysis of gamification's impact on computer science students' educational experience. Quantitative data from the questionnaires were analyzed using statistical methods to identify significant trends and correlations. Concurrently, qualitative data from the open-ended questions were analyzed using thematic analysis to identify recurring themes and patterns in students' perceptions and experiences. This dual approach facilitated a holistic

understanding of how gamification influences educational outcomes, supporting the validation of results through multiple data sources and offering rich, contextual insights into the effectiveness of the gamification elements integrated into the Answers platform.

2.4 Description of the Intervention

The "Answers" platform is a novel educational technology tool developed specifically for the computer science department at TU Delft. Designed to enhance learning, networking, and engagement through gamification, "Answers" is an alternative to traditional Q&A forums by incorporating elements that motivate and engage students and instructors in a more interactive learning process.

2.4.1 Technical Features

The Answers platform uses Ruby on Rails with MySQL as the primary database. It is a modification of the open-source platform Qpixel by the Codidact organization (https://github.com/codidact/qpixel). User data is protected through end-to-end encryption and secure data storage practices. The platform complies with GDPR, ensuring that user privacy is maintained. User authentication is handled via the TU Delft single sign-on (SSO) mechanism. The source code is available at https://gitlab.ewi.tudelft.nl/eip/answers/qpixel.

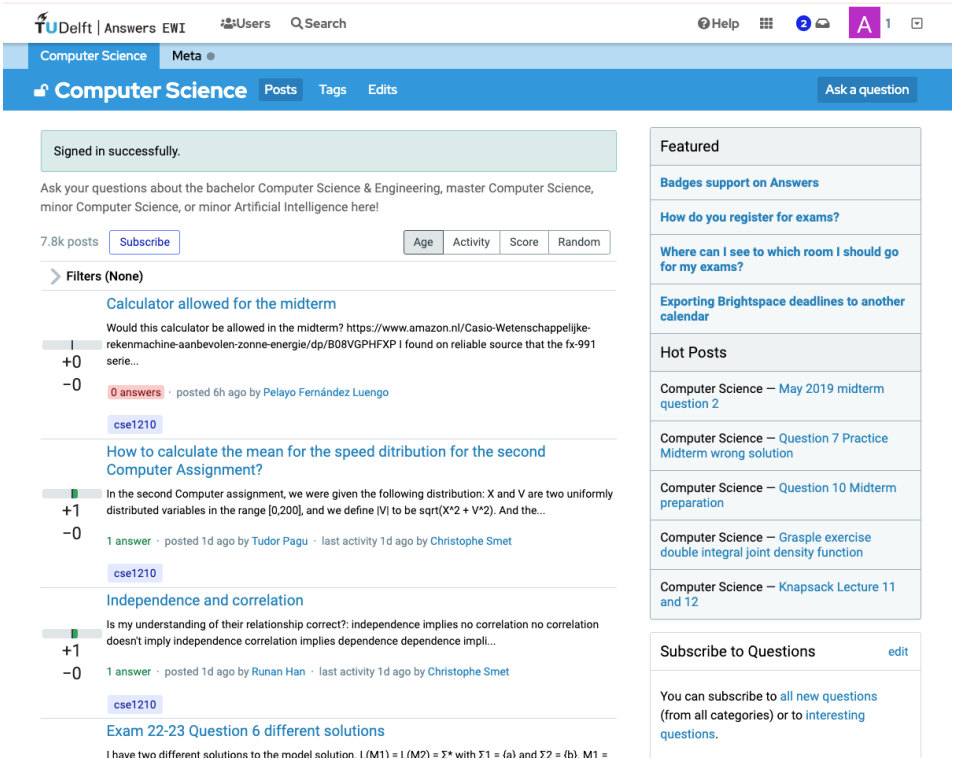

Figure 1: A Snapshot of Answers Platform

2.4.2 Design Principles

The platform features a user-friendly interface that allows participants to post questions, answer peers' inquiries, and engage in discussions. Each interaction on the platform is designed to foster a deeper understanding of computer science topics and to facilitate community building among students and faculty.

Key gamification features integrated into "Answers" include points, badges, and leaderboards. These elements were chosen based on their proven effectiveness in educational contexts (Deterding et al., 2011; Ibáñez et al., 2014). Points are awarded for participation activities, such as providing helpful answers and contributing to discussions. Badges are earned for reaching milestones and demonstrating proficiency in specific areas. The leaderboard showcases the most active and helpful participants, fostering a healthy competitive environment.

For the project's development, we started with an idea for a system where students could exchange information, building up a knowledge base for future years. We derived initial requirements for question and answer posting and searchability of previously answered questions. We looked for existing solutions and settled on

Codidact/Qpixel as a starting point for our application, which is available as open-source. From there, we made requirements for features that would improve the platform for use in education, involving various stakeholders like faculty and students to understand their needs and expectations. We had two Computer Science students work on implementing and integrating these features, following an Agile development methodology to ensure flexibility and responsiveness to user feedback. Finally, user testing sessions were conducted throughout development to identify and address usability issues. Both quantitative and qualitative data were collected to inform design decisions. Features that are generally useful are contributed back to Codidact.

After the initial deployment of the Answers platform, additional functionalities were added over time. Users were notified of new functionalities and instructed how they worked through the platform. Technical support was offered to address any emerging issues. Regular updates and feature enhancements were deployed based on user feedback. The platform's performance was continuously monitored through analytics, and feedback sessions were conducted with users to identify areas for improvement.

2.4.3 Engagement and Interaction Evaluation

We expanded the platform's analytics capabilities to evaluate user engagement and interaction patterns. We track various metrics, such as:

1. Number of Visits: Tracks the frequency students visit the platform. Higher visit frequency can indicate higher engagement.
2. Activity Frequency: Counts the number of activities performed by the users, such as posting questions, answering questions, and commenting. A higher frequency of activities can reflect active participation.
3. Achievement and Badges: Monitors the badges users earn and their progress towards achieving specific milestones. This data can reflect the effectiveness of gamification elements in motivating users.

The platform's design is based on the principles of Wenger's value creation framework, aiming to create immediate, potential, applied, and realized value for participants.

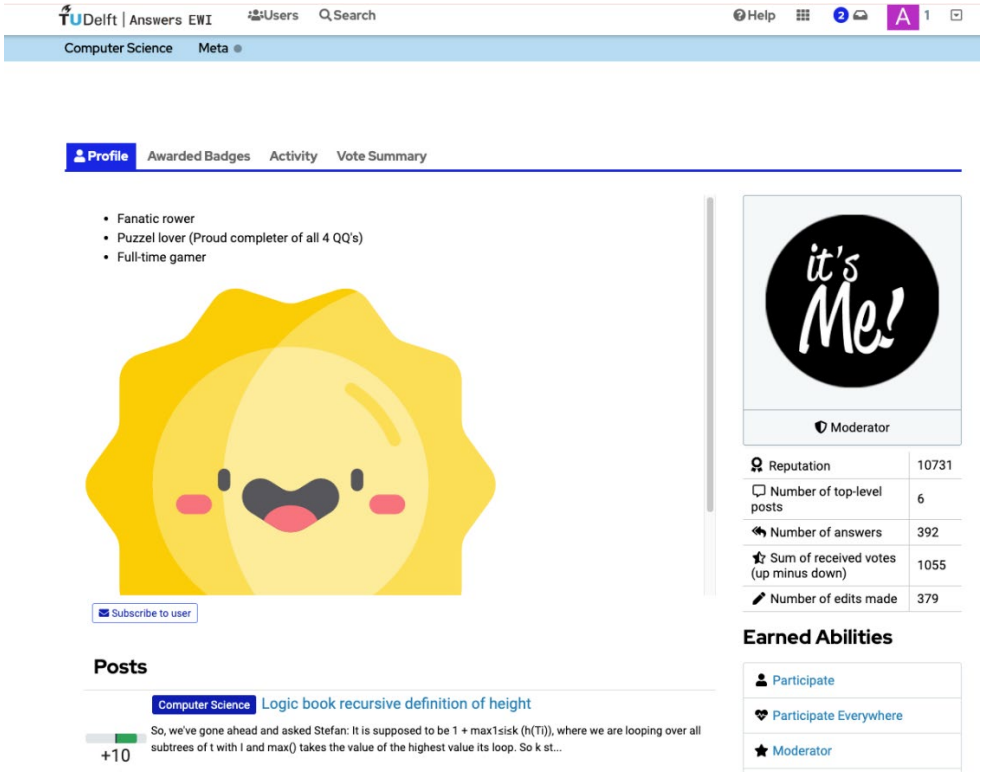

Figure 2: An example of Budges and Recognitions

This intervention was introduced at the beginning of the academic year. It was available to all computer science students and faculty, providing a real-time, dynamic environment for enhancing educational experiences through gamified learning.

2.5 Data Analysis

The analysis of the collected data from the "Answers" platform involved a comprehensive approach, utilizing both quantitative and qualitative techniques to ensure a thorough understanding of the effects of gamification on learning outcomes and motivation.

The qualitative data collected from the Value Creation Questionnaire were transcribed and analyzed using thematic analysis to identify recurring themes and patterns related to participants' perceptions of the gamification experience. Qualitative data analysis software (Atlas ti) facilitated the coding of the data, which helped organize the data into meaningful categories based on the value creation framework. This method allowed for the in-depth exploration of how the gamification elements influenced learners' motivation, perceived value from the platform, and overall learning experience.

A mixed-methods data integration technique was used to integrate the quantitative and qualitative findings. This approach involved comparing and contrasting results from both data sets to draw comprehensive conclusions about the study's hypotheses. By triangulating the data, we aimed to validate the findings across different methods, enhancing the reliability and validity of the results.

3. Results

3.1 Descriptive Analysis

3.1.1 Descriptive Analysis of Value Creation Questionnaire

Table 1: Descriptive results of VCQ

VCQ Components	Positive Value	Average	Std Dev
Immediate Value	38/60	3.7	1.36
Potential Value	9/60	2.08	1.18
Applied Value	53/60	4.51	1.17
Realized Value	24/60	2.88	1.30
Reframing Value	19/60	2.71	1.40

Table 1 provides a descriptive analysis of our Value Creation Questionnaire. This Questionnaire explores five cycles of value based on the value creation framework (Wenger et al., 2011). 38 Participants out of 60 indicated that the Answers platform created positive immediate value for them. In the open-ended question, they noted that, for example, Answers helped them Learn new materials and explore other students' questions. They described their experience as "Nice," "Useful," and "helpful." The other 22 participants who did not find the positive immediate value mentioned that they did not actively use the platform (7 out of 22) or did not find the platform helpful. For example, one of the participants mentioned:" I found the platform not to be so useful in general. Many of the questions were either very basic or debug/error related."

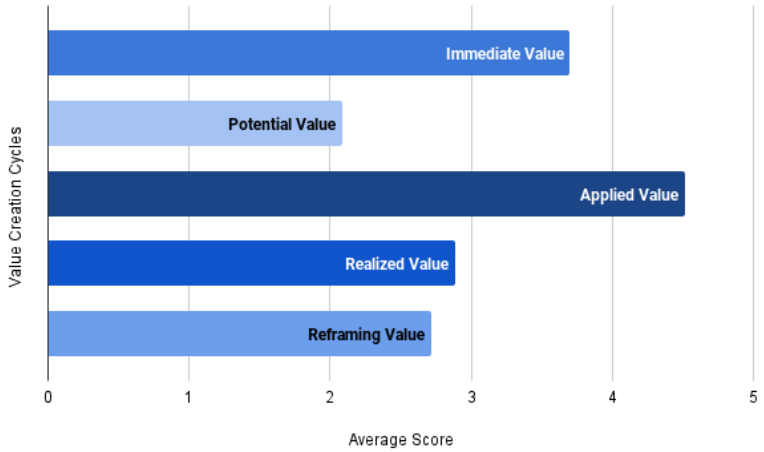

Figure 3: Average Score of Value Creation Cycles

The second part of VCQ explores relationships with peers and other students. Interestingly, only 9 out of 60 participants answered the second question (Participation affected my social connections (change in the number, quality, frequency, emotions, etc.)) positively, and the average score was 2.08. To elaborate on their experience, they mentioned, "I mainly use answers about the material rather than socializing per se."

The third part of this questionnaire explores the applied value that this platform can create for the participants. 53 participants out of 60 answered positively to the following question: “Participation helped my practices as a student (get new ideas, insights, materials, procedures, etc.),” and the average score was 4.51.

Our Fourth part investigates the influence of the Answers platform on participants' ability to influence the world as students (e.g., enhance my voice, contribution, status, recognition, etc.). 24 participants answered this question positively, and the average score was 2.88.

The last part investigates reframing value. Nineteen participants responded positively to this question: “Participation made me see my world differently (change in perspective, new understandings of the situation, redefine success, etc.),” and the average score was 2.71.

3.1.2 Descriptive Analysis of IMI

Table 2: Descriptive Analysis of IMI Subtests

IMI Subscale	Average	Std Dev
Relatedness	-0.30	0.59
Interest/Enjoyment	2.64	0.87
Perceived choice	0.82	0.78
Pressure/Tension	0.22	0.90
Effort	2.09	071

Table 2 illustrates the results of the descriptive analysis of the IMI questionnaire. The Relatedness subscale had scores clustering around the lower end, indicating that participants did not feel significantly connected to others through the platform. This suggests a need to improve social interaction features. Scores for Interest/Enjoyment were generally high, demonstrating that participants found the platform engaging and enjoyable. This aligns with the positive feedback on the platform's gamified elements.

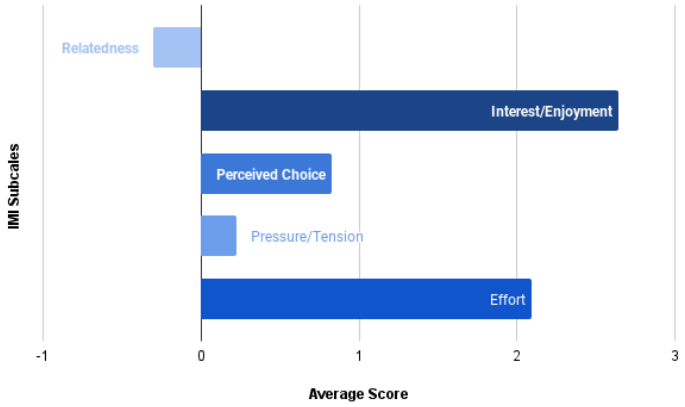

Figure 4: Average scores of IMI Subscales

3.1.3 Descriptive Analysis of Engagement and Interaction Analysis

The analytics module of the Answers platform provided detailed insights into user engagement and interaction. Key findings include:

Visit Frequency: The average number of weekly visits was 347, indicating regular engagement with the platform. As Figure 5 shows, participants constantly visit the Answers Platform, but we also see significant drops during holidays in weeks 8 and 14.

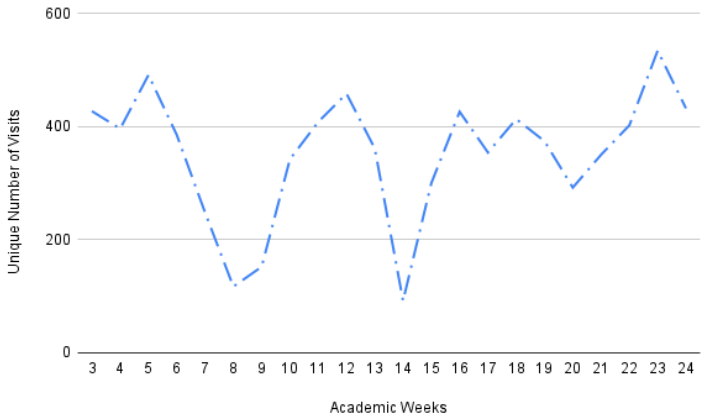

Figure 5: Visit Frequency

Activity Frequency: In total, our platform users raised 616 questions, answered 608 times, and left comments 395 times. Interaction Types: Most interactions were questions (38%), followed by direct answers (37%) and commenting (25%).

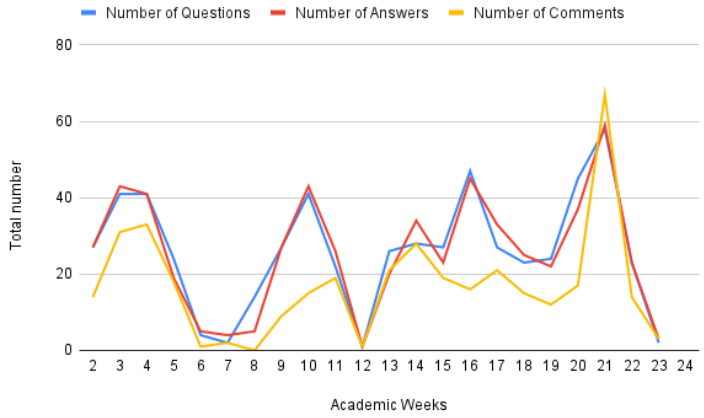

Figure 6: Activity Frequency of Answers Users

Badges Earned: Users earned a total of 428 badges during the study period, reflecting their achievements and milestones. The pattern shows the users' pick activity during exam periods.

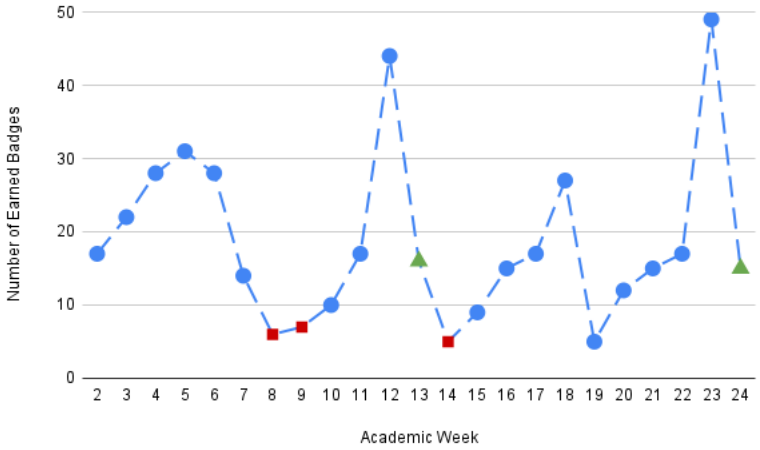

Figure 7: Total number of budges earned by Answers' users. Red squares indicate holiday weeks, and green triangles indicate exam weeks.

4. Discussion

This study aimed to investigate the impact of the Answers platform on student engagement and motivation using a combination of the Value Creation Questionnaire (VCQ) and the Intrinsic Motivation Inventory (IMI). The findings provide valuable insights into the efficacy of gamification in educational settings and its influence on various dimensions of the student learning experience.

4.1 Value Creation Framework Analysis

The VCQ results indicate a mixed but generally positive reception of the Answers platform among participants. Most students (38 out of 60) reported that the platform created positive potential value, with an average score of 3.18 out of 6. These students highlighted the platform's usefulness in learning new materials and exploring other students' questions, describing their experiences as "Nice," "Useful," and "helpful." This aligns with the first and second cycles of Wenger's value creation framework, where immediate and potential value is derived from the direct benefits and interactions within the platform.

However, 22 participants did not find immediate positive value, primarily due to their lack of active engagement (7 out of 22) or the perception that the platform's content needed to be sufficiently challenging and relevant. This suggests that while the platform has potential, its effectiveness is partly contingent on active participation and the quality of user contributions. Future iterations of the platform might benefit from strategies to enhance user engagement and ensure content relevance.

4.2 Social Connections

Interestingly, the platform's impact on social connections was less pronounced. Only 9 participants felt that their social interactions were positively affected, with an average score of 2.08. Many students indicated that they primarily used the platform for academics rather than socializing. This result suggests that while the platform is effective for academic support, it may not significantly enhance student social relationships. Enhancing features that promote social interaction and community building could be an area for future development.

4.3 Applied Value

The platform showed substantial success in creating applied value, with 53 participants affirming that it helped their practices as students, scoring an average of 4.51. This high level of applied value indicates that the platform effectively provides practical benefits, such as new ideas, insights, and materials, which students can integrate into their academic practices. This aligns with Wenger's notion of applied value, where the knowledge gained is utilized to improve practices.

4.4 Influence and Reframing

The platform's influence on students' ability to impact their world and perspectives was moderate. Twenty-four participants felt that their ability to influence their world as students improved (average score of 2.88), and 19 participants reported a change in their perspective (average score of 2.71). These findings suggest that while the platform does contribute to enhancing students' voices and altering their attitudes, there is still room for improvement in these areas. Encouraging more active and reflective participation could strengthen these aspects of value creation.

4.5 Intrinsic Motivation Inventory Analysis

The IMI results provide further insights into the motivational aspects influenced by the Answers platform. The relatedness subscale scored an opposing average of -0.30, indicating that the platform did not significantly enhance students' feelings of connectedness. Conversely, the interest/enjoyment subscale scored positively at 2.64, suggesting students enjoyed using the platform. Perceived choice scored moderately at 0.82, indicating some level of autonomy felt by students. Pressure/tension had a low positive score of 0.22, suggesting minimal stress associated with platform use, and effort scored 2.09, indicating that students were willing to invest effort into using the platform.

4.6 Engagement and Interaction

The descriptive analytics of engagement and interaction in the Answers platform highlight the platform's effectiveness in maintaining regular student involvement. The average number of weekly visits was 347, demonstrating consistent engagement with the platform throughout the academic term (Figure 5). This high visit frequency indicates that students frequently accessed the platform, likely finding it a valuable resource for their coursework. Additionally, the analysis of activity frequency showed that users actively participated by raising 616 questions, providing 608 answers, and leaving 395 comments (Figure 6). This distribution of interaction types, where questions constituted 38%, direct answers 37%, and comments 25%, highlights a balanced engagement across different forms of participation.

Moreover, users earned 428 badges during the study period, reflecting their achievements and milestones (Figure 7). The pattern of badge earning peaked during exam weeks, suggesting that gamification elements such as badges effectively motivated students to increase their activity during critical academic periods. These findings align with existing literature on the positive impact of gamification on student engagement and motivation (Deterding et al., 2011; Ibáñez et al., 2014), demonstrating that the Answers platform successfully fostered an interactive and supportive learning environment. Future iterations of the platform could explore additional features or incentives to enhance collaborative learning and student social engagement.

4.7 Implications and Future Directions

Overall, the Answers platform demonstrates the potential to enhance learning practices and provide enjoyable and valuable educational experiences. However, the mixed results regarding social connections and broader influences on student perspectives suggest that additional features to foster community engagement and more profound reflective practices could be beneficial. Future research could explore the impact of targeted interventions to increase active participation and platform content's relevance. Additionally, further studies could investigate the long-term effects of gamification on learning outcomes and motivation to build on the findings of this study.

By addressing these areas, the Answers platform could further its goal of creating a comprehensive and engaging learning environment that supports academic and social development for computer science students at TU Delft.

5. Conclusion

This study examined the impact of the Answers platform, a gamified learning tool, on computer science students at TU Delft. We explored the platform's influence on students' learning outcomes, motivation, and value creation through a mixed-methods approach. The findings indicate that while the platform successfully enhances learning practices and engagement, its impact on social connections and broader perspectives is less pronounced. The mixed results highlight the potential of gamified learning environments to improve educational experiences while pointing to areas for further enhancement. Future research should focus on strategies to increase active participation and foster a sense of community, ensuring the platform's content remains relevant and challenging. The Answers platform can further its mission of creating a dynamic and supportive learning ecosystem by addressing these aspects.

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