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Cyberstorm: Using Gamification in Cybersecurity Education

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Abstract

For more than a decade, game-like elements such as point scoring, leaderboards, competition, challenges, and collaboration have been incorporated into fields far beyond gaming and technology[1]. This practice, known as gamification, has been shown to improve customer satisfaction, user activity, social interaction, content retention, and motivation across domains ranging from marketing and commerce to health, innovation, and education[1,2,3].

In this paper, we present the results of integrating these gamification elements into a cybersecurity course taken by over 100 sophomore to senior Computer Science and Cyber Engineering students at our institution. While individual elements, such as competition and collaboration, have been studied extensively in other contexts, our work examines their impact on a student population already familiar with gamification and provides insights into their educational experiences.

Our findings indicate that gamification makes the study of cybersecurity more engaging and rewarding, and when well designed can have a significantly positive impact on students' ability to collaborate. Moreover, we identify which specific elements are most effective in achieving student engagement and which elements contribute to student stress and pressure. Notably, our findings show that the gamification elements that heighten student pressure often are the same elements that sustain engagement. These results suggest that well-designed gamification is a viable approach for increasing student engagement and content retention in technical education, both within and beyond Computer Science.

Introduction

Computer Science is a field that is plagued by low retention rates. Multiple studies have been devoted to this situation with reported drop out rates ranging from 9.8%[4] to 28%[5]. At Louisiana Tech University, we routinely see a steep drop off in student numbers as students progress through our own Computer Science curriculum with the total number of students who completed our core junior level class being 54% of the total number of students who completed our second freshman Computer Science class in the same time period.

One of the reasons for the low retention rates in Computer Science is low student engagement[6,7]. Computer Science and its subfields cover a lot of complex and sometimes abstract concepts, the mastery of which typically requires extra effort from students compared to other fields; effort that some of the students are not willing or capable of giving.

Stagnant pedagogical approaches is another reason for low engagement and retention rates in Computer Science[8]. Even though the field changes frequently, many of the core foundational principles do not. Without intentional steps, the routine and rigor in many core classes can end up being out of sync with the changing level of prior knowledge, exposure and skills that a typical Computer Science student in that institution starts the class with.

In addition to stagnant curricula, pedagogical approaches can also become stagnant through a limited variety of evaluation techniques in traditional classrooms. While exams and programming

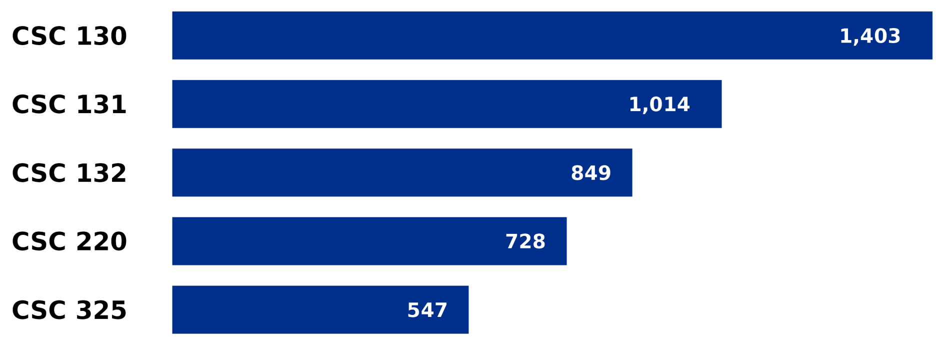

Figure 1: The size of our institution's first 5 Computer Science classes shows a significant drop in numbers as students progress through the curriculum.

assignments remain the standard tools for assessment, they can be challenging to administer frequently either due to the need to test a broader range of concepts or because of larger class sizes[9]. Previous work[3,10] has demonstrated the effectiveness of incorporating challenges and competitions, showing that they can enhance students' understanding of the material, standardize comprehension across different teaching styles, and, to some extent, mitigate differences in content coverage duration.

In this paper, we present Cyberstorm: an attempt at utilizing gamification as an approach to solving the problems of curricula stagnation, low student engagement, and low retention within the subfield of Cybersecurity education. Gamification is the process of incorporating elements and principles typically found in games, particularly video games, into non-game contexts in an effort to make them more engaging, motivating and enjoyable[11]. Some of these elements include points, levels, challenges, leaderboards, progress tracking, and rewards. The incorporation of these elements taps into people's natural drives for achievement, competition, recognition, collaboration, and mastery.

Incorporating gamification solves the problem of curricula stagnancy because it adapts a curriculum to meet the changing prior exposure and skills of the students. Even though the field of Gamification has existed for over 15 years, the average student's familiarity with it or even preference for it was never considered mainstream. However, these days the average computer science student is intimately familiar with video games, and this presents a prior skill set that could be leveraged in the design and development of novel pedagogical approaches within Computer Science in general, and Cybersecurity more specifically.

Well designed gamification also provides an additional tool for instructors to use in evaluating the level of content mastery that students have in their classes. While exams and programming assignments are the classic evaluation tools preferred within this field, gamification elements can be used to develop low stress alternatives to complement the traditional evaluation approaches[11,12,13].

Gamification also provides an opportunity to incorporate and evaluate skillsets that are valuable to professionals in Computer Science, but difficult to embed into traditional classes with classical evaluation approaches. While collaboration, and similar soft skills are a valuable tenet of a complete Computer Science education, they are typically difficult to incorporate into a traditional Computer Science classroom. Well designed gamification provides easy ways to incorporate collaboration into and evaluate it within any curriculum[11,14] .

In this paper, we present the results from integrating multiple gamification elements into three sections of a college Cyber security course. These results show the insights of over 100 sophomore to senior Computer Science and Cyber Engineering students at our institution into a few areas such as: the efficacy of gamification in education, the impact of gamification on student engagement, and the identification of which gamification elements contribute to student engagement and student stress or anxiety.

While the study was done within Cybersecurity education, the work herein is valuable to instructors, curriculum designers, and administrators from different fields. For instructors and curriculum designers, this work can inform their decisions as they identify which gamification elements to incorporate into their curricula to improve student engagement while controlling student anxiety. This work is also valuable for any curriculum designers and administrators who are considering a curriculum redesign to deal with curricula stagnation, low student engagement, or low retention[15].

The rest of the paper is organized as follows: In the Related work section, we highlight other studies that have been carried out to deal with the issues of student motivation, engagement, and stress within Cybersecurity, Computer Science and other fields. In the methodology section, we discuss the structure of the class highlighted in this study, the challenges incorporated in that class, and the details of our research process. In the results section, we present both qualitative and quantitative results covering general student feedback, and how specific gamification elements might have contributed to their engagement or anxiety. We then conclude the paper with a discussion of the efficacy of individual gamification elements, and how this work can be applied to other classes, fields, or institutions.

Related Work

Gamification is the process by which elements of game design are incorporated into non-game contexts and is typically used to improve user engagement, experience, and motivation. The specific elements incorporated depend on the study and the context in which they are applied; however, common elements include points, badges, leaderboards, levels, challenges, and avatars. These elements are designed to provide feedback to users and administrators alike, including, but not limited to, information about progress during a task.

One context in which gamification has been widely applied is healthcare and medical education[15]. For example, an interdisciplinary escape room was successfully used to teach students about psychiatry, infectious diseases, and communication skills[16]. Gamification has also been applied to improve the digital literacy of elderly populations with respect to electronic health records[17]. Additionally, board games and immersive simulations have been employed to achieve learning outcomes in pharmacy education[18]

In the business sector, gamification has been employed to improve brand loyalty, customer engagement, and motivation. Common initiatives such as frequent flyer programs use rewards as a form of gamified currency, leveraging the idea that gamification can positively influence customer engagement[15]. Other services offer points, titles, and rewards for frequent check-ins or task completion, as well as gamified incentives to encourage survey participation. In this domain, an understanding of user behavior informs the selection of game mechanics and gamification elements integrated into the overall user experience.

Gamification has also been applied within social science and humanities education, with application areas ranging from religious education to history. In these contexts, it has been used to encourage the development of skills such as diplomacy and negotiation[11].

The impact of gamification across genders has been examined in several studies[19,20,21], though the findings remain inconclusive. For instance, Legaki et al.[19] reports that challenge-based gamification has a greater positive effect on learning outcomes for females than for males. In contrast, Melado et al.[20] finds that women achieve significantly better learning outcomes in non-gamified environments compared to men. Meanwhile, Li et al.[21] suggests that gamification can provide an inclusive learning approach, with both genders achieving comparable learning gains, even if their levels of motivation or enjoyment differ.

Inevitably, gamification has found extensive application within computer science education. Examples include its use in teaching 3D computer graphics and modeling, as well as computer game design[22]. It has also been employed to provide structured learning environments that encourage students to master complex topics such as data structures and algorithms[10] and artificial intelligence. In these studies, gamification was used to connect abstract or complex technical concepts to concrete, interactive examples, resulting in improved learning efficiency, content retention, and student engagement.

One area within computer science where gamification has been particularly prevalent is programming and software engineering[23]. Even within this subfield, its applications range from introductory programming courses aimed at increasing student willingness to engage with complex material to sophisticated tools designed to train software engineers in concurrent and parallel programming[24]. Gamification has also been used in high-intensity extreme programming courses to enhance team engagement.

The most pertinent field for this work, however, is cybersecurity. Within this subfield, gamification has been applied to workforce training[25], often incorporating scenario-based narratives derived from real-world historical cyber incidents. Gamification has also been used in computer networking courses, at times integrated with established platforms such as Cisco's Network Academy[23].

Our work contributes to the growing body of evidence supporting the efficacy of gamification within computer science education. It is distinct in its emphasis on the roles of collaboration and competition within gamified environments and provides insights into how to maximize the benefits of gamification while mitigating drawbacks reported in prior studies. Additionally, this work presents results on engagement, as well as the stress and anxiety associated with individual gamification elements, offering valuable guidance for institutions and researchers seeking to design gamified environments that maximize engagement while minimizing negative impacts.

Methodology

This section is organized into three parts. The first provides an overview of the cybersecurity course in which the study was conducted. The second describes how gamification was implemented in the course, and the third outlines the research approach used to produce the results presented in this paper.

Class Design

The course examined in this research is the *Introduction to Cybersecurity* class offered at our institution. It is offered as an elective for traditional computer science students, a required course for those pursuing a Cybersecurity concentration, and a required course for students in the Cyber Engineering program. The course is taught twice each year, with two sections typically offered in the Spring quarter and one in the Fall quarter, each enrolling approximately 30–40 students. The data used in this study were collected from the Spring 2025 and Fall 2025 offerings, representing a total of 109 students. The course covers a broad range of cybersecurity subdomains, including cryptography, reverse engineering, covert channels, access control, and network reconnaissance, each organized as a standalone module with dedicated instructional time, content, and assignments.

Each module concludes with a collaborative in-class challenge designed to assess mastery of the current material while occasionally integrating concepts from earlier modules. These challenge activities are completed by student groups within a single class period, with seven such challenge days scheduled across the term. The course also culminates in a *Cyberstorm* event, a day-long competition in which teams of up to six students attempt a large pool of challenges. While most challenges assess comprehension of course content, others emphasize the development of broader skills such as problem solving, independent research, effective use of prior knowledge, and collaboration.

Gamification Elements

Multiple gamification elements are embedded in the design of both the challenge days and the Cyberstorm event. In this section, we describe each of the elements incorporated into the study, along with the rationale for their inclusion.

Themes

The Cyberstorm event has been a long-standing tradition at our institution for over a decade. Each year, students in the course are invited to propose, discuss, and vote on a theme. The selected theme is then integrated throughout multiple aspects of the course, including team names, challenge design, promotional posters, event graphics, T-shirts provided to participants, and swag awarded to winning teams. Past Cyberstorm themes have included Dinosaurs, Tarot Cards, and Cryptids.

Incorporating a theme enables the use of engaging narratives to contextualize abstract theoretical concepts[26]. Unified storylines, plots, and narrative themes help gamification recipients move beyond short-term goals toward long-term change by linking seemingly isolated tasks, providing students with a sense of purpose, and enabling them to reach a “state of flow” during challenges[27,28,29]. In our case, this narrative framework also allows challenges drawn from disparate cybersecurity subfields to be unified into a cohesive experience.

Giving students a voice in selecting the theme fosters a sense of ownership and buy-in for both the course and its challenges. By connecting cybersecurity concepts to external themes aligned with student interests, the class becomes more personally meaningful. Rotating the theme annually further allows the course and its challenges to remain responsive to the evolving interests of each student cohort. Additionally, student teams also select their own names based on the annual course theme. For example, the theme during this study was Cryptids, and team names included Bigfoot, Yeti, Rougarou, Mothman, and Wendigo, etc.

Teams

Students in the course are assigned to teams of up to six members by the instructor. Team formation is informed by a self-evaluation completed at the beginning of the term and is designed to ensure balanced groups that include students with diverse backgrounds and skill sets.

Most assignments and challenges are team-based, providing students with regular opportunities to develop collaboration and leadership skills. In most cases, all members of a team receive the same grade for group assignments. However, the course includes safeguards to address disruptive or non-collaborative behavior. One such mechanism involves replacing team scores with individual scores when there is a significant and sustained discrepancy in student contributions.

Competition

Student teams compete against one another through two primary mechanisms.

The first form of competition occurs during *Challenge Days*, which are distributed throughout the academic term. Each Challenge Day consists of a single class period in which teams are presented with one challenge designed to assess their understanding of material from the most recently completed module. A low-stress environment is promoted by playing music during the activity and encouraging inter-team discussion. This collaborative atmosphere allows teams to jointly analyze the problem and implement their solutions. The team that completes the challenge correctly in the shortest amount of time is declared the winner and receives a reward unrelated to course grades. Grades for Challenge Days are instead determined by the accuracy and completeness of each team’s solution.

The second competitive component is *Cyberstorm*, a single day-long event held at the end of the term. During Cyberstorm, teams are given access to a large pool of challenges, each assigned a different point value and requiring varying amounts of time to complete. Student teams must strategically select which challenges to attempt and when in order to maximize their overall score because the total number of challenges and the cumulative time required exceed what any single team can complete. At the conclusion of the event, the team with the highest total number of points is declared the winner of Cyberstorm.

Figure 2: Faculty and students participating in recent Cyberstorm events

Challenges

In this context, challenges are multi-step problems based on content from one or more cybersecurity subfields that require a substantial time investment from an individual or team to complete. For Challenge Days, challenges are designed to be solvable within a single class period by the assigned team. For the Cyberstorm event, challenges are structured so that up to three team members can complete them within approximately four hours.

For example, a challenge following a cryptography module requires students to solve a sequence of classical encryption and encoding problems. Students are provided with text files—some encoded in binary—that must be translated using ASCII and decrypted using schemes such as Vigenère, Scytale, Caesar, and Base64. Completing these steps leads to a final message that the team submits to the instructor to confirm completion.

Challenges are generally structured in sequential, parallel, or hybrid formats. Sequential challenges require completing one subtask to gain the information needed for the next, which makes it easier for instructors to identify struggling teams and provide targeted guidance. Parallel challenges allow multiple subtasks to be attempted in any order, facilitating team collaboration by letting members divide tasks among themselves. Hybrid challenges combine these approaches, with some tasks sequential and others parallel; this format is the most common, balancing team dynamics with instructor oversight.

Most challenges are designed by the course instructors and are closely tied to the modules covered in class. However, a significant number of Cyberstorm challenges are contributed by former students, alumni, and industry partners.

Leaderboards

Leaderboards are a key gamification element used in both Challenge Days and the Cyberstorm event. On Challenge Days, the leaderboard typically consists of a publicly displayed log showing which teams have successfully completed the challenge and the time of completion. The team that finishes the challenge in the shortest time is declared the winner for that day.

During Cyberstorm, the leaderboard is presented as a webpage projected on a large screen in the event space, displaying the current points accumulated by each team. As teams complete challenges, their scores are updated in real time, allowing all participants to track their own ranking relative to others. The team with the highest total points at the end of Cyberstorm is declared the overall winner.

Public leaderboards foster a sense of competition and motivation, helping maintain student engagement throughout both Challenge Days and Cyberstorm[21,30]. Real-time updates allow teams to gauge their standing, adjust strategies, and select challenges that can improve their position in the overall rankings.

Rewards

Rewards are given to teams that win a Challenge Day, distinguish themselves during a Challenge Day, or win the Cyberstorm event. These rewards are designed to motivate participation without impacting course grades, ensuring that success in challenges encourages engagement rather than penalizing students who may struggle. As such, rewards for completing challenges first are small, symbolic items that do not affect academic evaluation.

During Challenge Days, winning teams receive themed swag based on the class theme. For example, with this year's Cryptids theme, rewards included laptop stickers and fridge magnets featuring the Cyberstorm logo and cryptid illustrations. This reward is given only the first time a team wins a Challenge Day. Instructors may also award swag to teams that demonstrate creativity or overcome particularly difficult obstacles, ensuring that every team receives recognition at least once during the term. Another Challenge Day reward allows the winning team to curate the music playlist for the next Challenge Day.

For the Cyberstorm event, the team with the highest total points at the end of the day is announced, celebrated, and awarded a copy of that year's Cyberstorm poster signed by their classmates. Overall, the rewards are memorable but affordable, enhancing motivation and a sense of achievement while preserving the integrity of course grades. Student evaluation remains based on mastery of the material rather than the speed or success of completing challenges.

Levels

Levels are another gamification feature integrated into the course to indicate student progress and increasing challenge complexity. Many Cyberstorm challenges are multi-level, with each level providing partial credit. Levels are typically marked by flags that teams can submit for credit while also serving as essential information to advance within the challenge.

Challenge Days are similarly structured with increasing complexity over the term, reflecting the growing knowledge students are expected to acquire. Later challenges often incorporate subtasks spanning multiple cybersecurity subfields, testing both recent and previously covered concepts.

The use of levels within individual challenges helps instructors identify choke points and provide targeted guidance, while giving teams partial credit for progress rather than only for completing the full challenge. Across Challenge Days, levels maintain student engagement and motivation by offering multiple opportunities to demonstrate mastery and allowing instructors to build on students' skills and knowledge iteratively throughout the term.

Data Collection

Data for this study was collected from approximately 109 undergraduate computer science and cyber engineering students enrolled across three course sections over two academic terms. To capture both population-level trends and contextualized student experiences, this study employed a mixed methods approach, integrating quantitative surveys with qualitative small-group interviews.

Two data collection methods were used:

1. structured online surveys, and
2. small-group interviews conducted in class following completion of a gamified assignment.

These methods were selected to capture students' perceptions of the gamified course design while minimizing disruption to instructional activities.

Survey data was collected at two points during the term to examine changes in student perceptions over time. A baseline survey administered on the first day of class captured students' prior experiences with and attitudes toward gamification. A post-course survey administered on the final day of class captured end-of-term reflections and included Likert-style items (ranging from strongly disagree to strongly agree) and multiple-choice questions assessing motivation, stress, satisfaction, and perceptions of competition.

Because survey data alone could not fully explain the factors underlying students' reported perceptions, qualitative data was gathered through small-group interviews with the student teams after Challenge Days. These interviews elicited immediate reflections on the gamification experience, with particular emphasis on sources of stress and engagement, as well as the roles of collaboration and competition. All interviews were audio-recorded and transcribed for analysis.

Interview transcripts were analyzed using a hybrid thematic approach. Initial coding applied predefined concern categories derived from the survey instruments, including *team pressure*, *general stress*, *competition-related discomfort*, and *no concerns*. Subsequent inductive analysis allowed for the identification of emergent themes, such as *time constraints*, *grades*, and *task ambiguity*, capturing recurring sources of stress and pressure not fully represented in the survey data.

The integration of quantitative and qualitative findings enabled triangulation, allowing population-level trends to be interpreted alongside student accounts that elucidated how and why specific elements of the gamified course design shaped their experiences.

Participation in the study did not affect course grades. Students were informed of this at the start of the term and provided written consent acknowledging the study's purpose, the voluntary nature of participation, and their right to withdraw at any time.

Results

Table 1: Participant background characteristics, including demographics, gaming habits, and familiarity with gamification in education.

(a) Age

Range	Freq.
18-20	54
21-25	50
26+	3

(b) Gender

Gender	Freq.
Female	16
Male	90
Not disclosed	1

(c) Play Video Games

How often	Freq.
Frequently	88
Occassionally	12
Rarely	6
Never	1

(d) Prior Gamification

Familiarity	Freq.
Yes	96
No	7
Not Sure	4

To understand the impact of gamification in this context, it is first necessary to examine the student population to which the study was applied. Table 1 presents the demographic breakdown of the participants and provides insight into their prior exposure to video games and gamification in education. This familiarity with gaming and prior experience with gamified systems are characteristics of so-called "digital native" students[22]—learners with distinct profiles, diverse learning preferences, and heightened expectations of the educational experience shaped by long-standing engagement with digital technologies[31].

The remainder of this section reports qualitative and quantitative findings from systematically conducted surveys and interviews involving up to 107 students across three course sections and two academic quarters. The section is organized into three parts: (1) changes in student perceptions of core gamification tenets over the duration of the course, (2) qualitative insights from student interviews, and (3) student feedback on the balance between motivation and pressure or stress associated with the four primary gamification elements employed in the class.

Student Perceptions of Gamification

Students' expectations, perceptions, and concerns regarding gamification were assessed both before and after the class, providing insight into how the implemented gamification elements influenced their learning experience.

Figure 3 shows changes in student expectations and impressions over the course of the class. For example, 87% of students initially expected gamification to increase engagement with the material. By the end of the class, 78% reported that it had indeed led to greater engagement. Although this category experienced the largest decline, "more engagement with the material" remained the area most positively impacted by gamification. Another notable factor is the "sense of collaboration." Before the class, only 53% of students anticipated that gamification would enhance collaboration, but this figure rose to 71% by the end, indicating that gamification fostered teamwork even in areas students had not initially associated with it. Other areas—including creating an enjoyable learning environment, providing a competitive push, and increasing motivation—scored consistently high (71–73%) and students' perceptions of their impact remained largely unchanged throughout the course.

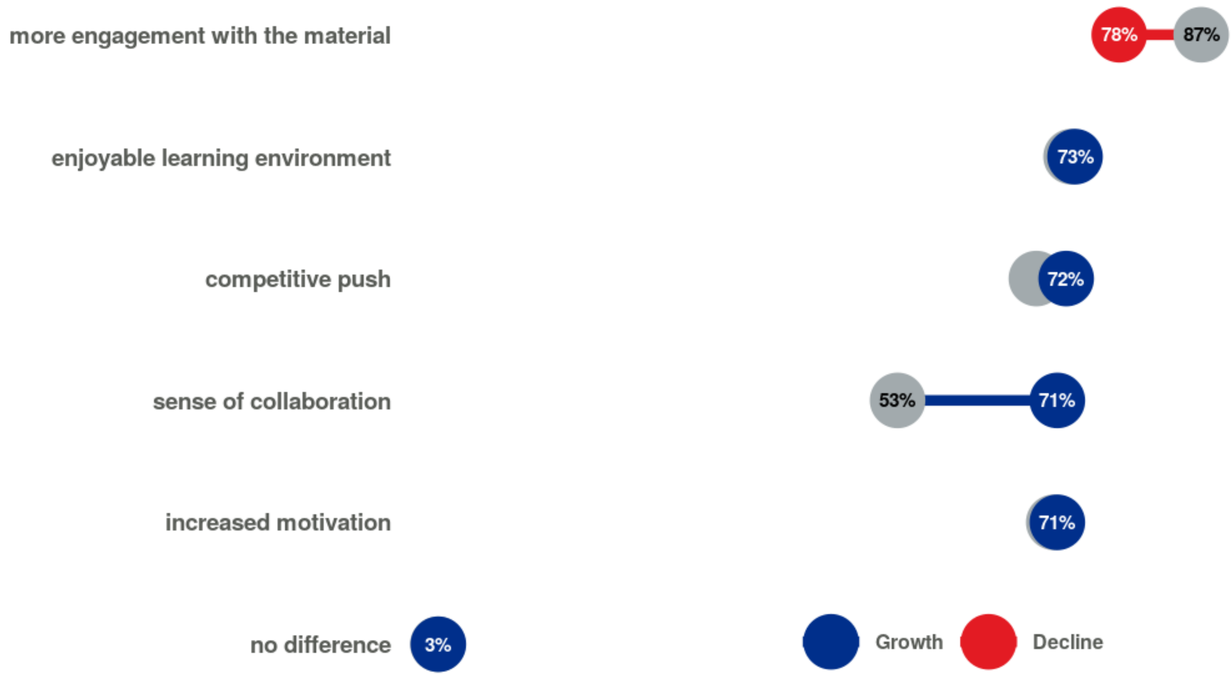

Figure 3: Students were asked about their expectations before using Gamification in the class, and after using Gamification in the class. Some of the categories showed an increase, while others showed a decrease.

Students were also asked about potential concerns related to gamification (Figure 4). Initially, 42% of students expected that increased pressure to perform for their team would be a concern, which rose slightly to 45% by the end. In contrast, concern about increased stress decreased from 42% to 39%. Students who initially felt uncomfortable with competition decreased from 13% to 7%, while concern regarding the collaborative aspect of the class, initially absent, emerged for 4% of students by the end.

The most striking shift in perceptions was observed in students' preferences for team versus individual work (Figure 5). The proportion of students preferring to work alone dropped from 21% to 10%, while those favoring team-based work increased from 20% to 39%. While gamification research often focuses on enhancing motivation or engagement, these results demonstrate that, with intentional design, gamification can also significantly improve students' ability and willingness to collaborate. This is particularly relevant in computer science and cybersecurity education, where curricula typically emphasize technical content over soft skills such as teamwork. Thus, beyond increasing engagement, gamification can be leveraged to cultivate essential soft skills.

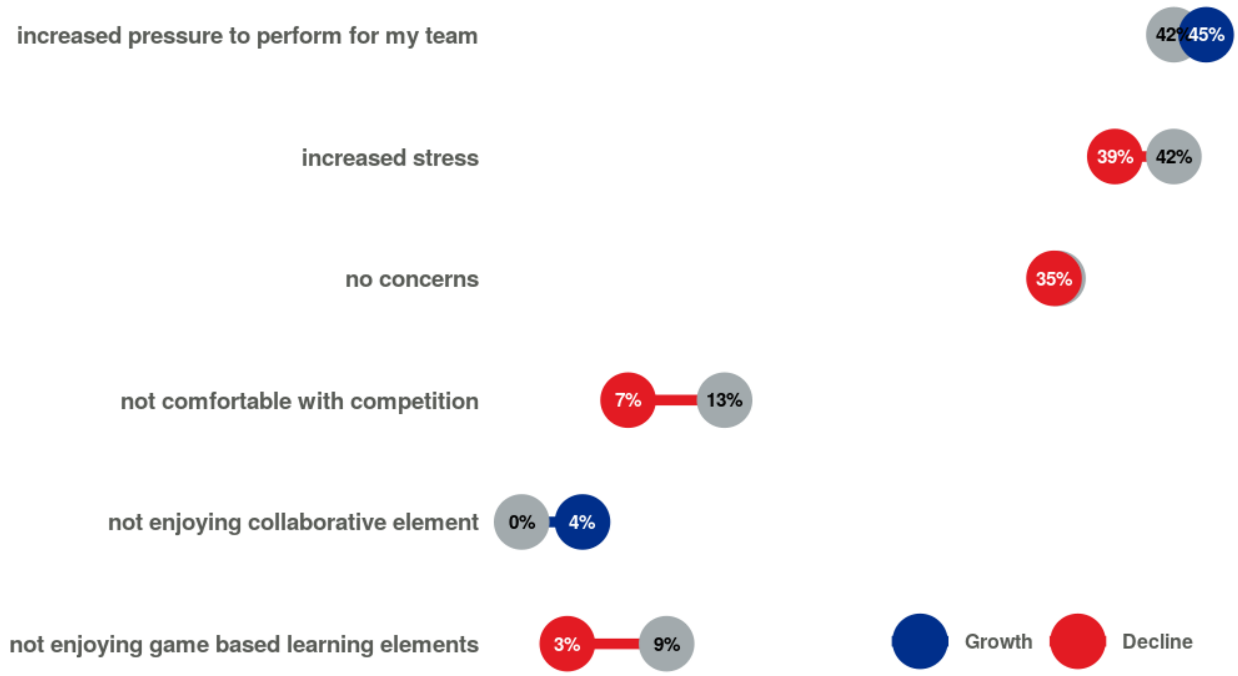

Figure 4: Students were asked about their concerns before using Gamification in the class, and after using Gamification in the class. Some of the categories showed an increase, while others showed a decrease.

Qualitative Findings from Student Interviews

Across interviews, students most frequently described *team-related pressure*, characterized by a desire to contribute, "pull their weight," and avoid letting teammates down, even when they did not characterize the experience as stressful overall. One student remarked that their pressure came from "performing for the team because I didn't want to be useless twiddling my thumbs."

Students also commonly identified general stressors unrelated to teamwork, such as time constraints. One student reported that completing the assignments was "much more stressful" because of "time limits." Another stressor was uncertainty about where to begin or which tools to use. For some students, these concerns were compounded by grade-related pressure and fear of poor performance.

In contrast, several participants explicitly reported experiencing no meaningful stress or concerns, often attributing this to working within a team and having the flexibility to continue work outside of class with students reporting that "teamwork...relieves the stress", and "I don't really feel pressured because we have a team". Another student mentioned that "inside our team, we don't pressure each other...we help each other out."

Competition was identified as a source of pressure for some students; however, it was more often framed as motivating rather than negative, with students describing a desire to win or finish first.

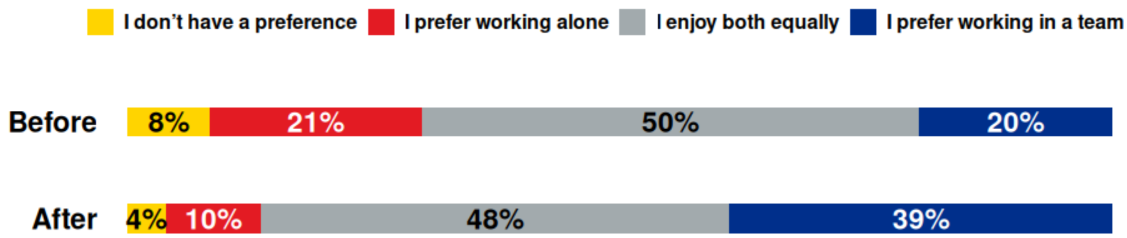

Figure 5: Students' perceptions about working in a team or individually also changed over the course of the term

One student expressed that they were "motivated by the bragging rights of winning." Comparatively few comments suggested discomfort with competition itself.

Notably, negative perceptions of collaboration or of game-based learning were rare or absent in the interviews. This suggests that the most salient sources of concern were not the gamified format itself, but rather performance expectations and constraints related to time and grading.

Motivation and Engagement versus Stress and Pressure

Together, these results highlight generally positive perceptions of gamification, particularly in terms of engagement, collaboration, and teamwork. However, a recurring theme in the qualitative data was that some of the same gamification components that increased motivation and engagement also contributed to feelings of stress and pressure.

To examine this tension more closely, we supplemented the quantitative surveys during the second term of the course with additional questions focused specifically on these concerns. The results presented in the following subsection summarize findings from those surveys. It is important to note that, unlike the preceding analyses, these results were drawn exclusively from the most recent single section of the class, which included a total of 38 participants.

Figure 6 presents students' perceptions of four specific gamification elements that emerged repeatedly in the qualitative interviews: points and rewards, leaderboard rankings, teammates, and time constraints. Each row illustrates students' agreement with statements reflecting both the motivational and engaging aspects of these elements, as well as their associated stress and pressure, measured using a five-point Likert scale ranging from Strongly Disagree to Strongly Agree.

For example, 37% of students strongly agreed that the points and rewards system was engaging and satisfying, 34% agreed, 26% were neutral, and 2% disagreed. In contrast, 39% strongly agreed that the same system added pressure to perform well, 47% agreed, 8% were neutral, and 5% disagreed. These mixed responses were reflected in student comments, with one student noting motivation to earn recognition such as having their playlist played in class, while another stated they "just wanted a fridge magnet."

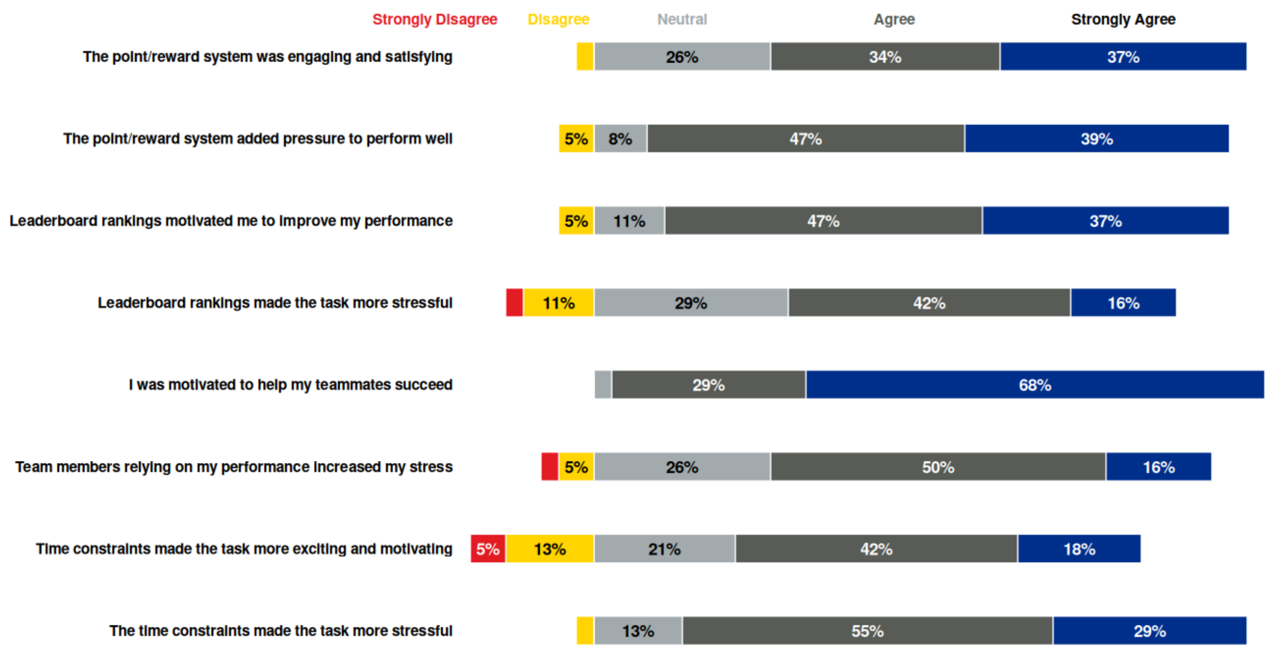

Figure 6: Do gamification elements increase motivation and engagement or do they increase stress and pressure?

A similar pattern emerged for team-based elements. Regarding motivation, 68% of students strongly agreed that they were motivated to help their teammates succeed, 29% agreed, and the remaining 3% were neutral; no students expressed disagreement. Conversely, 16% strongly agreed that teammates' reliance on their performance increased their stress, 50% agreed, and 26% were neutral, while 5% disagreed and 3% strongly disagreed. Students described being "motivated to perform for the team and not be dead weight," while others noted increased pressure when comparing their progress to teammates who were completing tasks more quickly.

The discussion about leaderboards as an element of Gamification yielded similar results. 58% either Agreed or Strongly Agreed with the statement that leaderboard rankings made the tasks more stressful but 84% either Agreed or Strongly Agreed with the statement that leaderboards motivated them to improve their performance.

Time constraints was another element that came up repeatedly but more often than not, it was in regard to the In-Class challenges. Students reported feeling pressure to complete the task within the class time as opposed to having to meet with their teammates after class time to complete the challenge and submit a report before the official deadline. Any teams that completed the task within the class time could potentially submit their report by the end of the class time and not have that hanging over their heads outside of class.

Conclusion

This study examined the impact of gamification in a computer science course by analyzing both quantitative survey data and qualitative student feedback across multiple course sections and academic terms. Overall, the results indicate that gamification positively influences student engagement, motivation, and collaboration. Students reported increased engagement with course material, a more enjoyable learning environment, and enhanced motivation, with collaboration emerging as an area where gamification exceeded initial expectations. Notably, students' preferences shifted toward team-based work, suggesting that well-designed gamified environments can meaningfully support the development of teamwork skills—an outcome often underemphasized in technically focused computer science and cybersecurity curricula.

At the same time, the findings highlight an inherent tension in gamified course design: the same elements that drive motivation and engagement can also introduce stress and pressure. Points, rewards, leaderboards, and team dependencies were frequently cited as both motivating and stress-inducing. While many students reported feeling energized by accountability to their teams and by competition, others experienced increased pressure related to performance comparisons and time constraints. These results underscore the importance of intentional design choices, particularly in balancing motivational incentives with psychological well-being and ensuring that competitive and collaborative elements remain supportive rather than punitive.

Several limitations should be acknowledged. Although the study spans three course sections and two academic terms, it was conducted within a single institutional and course context, which may limit the generalizability of the findings to other settings, particularly those with different student demographics or levels of prior exposure to gamification. Additionally, the reliance on self-reported survey data introduces the possibility of response and perception bias, as measures of engagement, motivation, and stress may vary across individuals. Uncontrolled factors, such as team composition and prior familiarity with competitive or collaborative environments, may have also influenced student experiences. As such, the findings should be interpreted as context-dependent rather than universally applicable.

Taken together, this work suggests that gamification, when thoughtfully implemented, can extend beyond engagement to foster essential soft skills such as collaboration and accountability, while still requiring careful calibration to mitigate unintended stress. Importantly, these findings raise the question of whether there exists a threshold of pressure beyond which gamification shifts from being beneficial to detrimental to student learning and well-being. Future work should investigate this potential tipping point by examining how varying levels of competitive, time-based, and team-dependent elements influence student outcomes. Such efforts could inform design guidelines that maximize motivational benefits while minimizing adverse effects, ultimately supporting more sustainable and inclusive gamified approaches in computer science education.

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