Evaluating the Effectiveness of Gamification on Students' Performance in a Cybersecurity Course

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Abstract - The motivation of students to actively engage in course activities has significant impact on the outcome of academic courses. Prior studies have shown that innovative instructional interventions and course delivery methods have a vital role in boosting the motivation of students. Gamification tools aid course delivery by utilizing well established game design principles to enhance skill development, routine practice and self-testing. In this article, we present a study on how the use of a course gamification platform dubbed OneUp impacts the motivation of students in an online cyber security course. The study shows that more than 90% of the respondents agreed that OneUp has improved the effectiveness of the course delivery. In addition, 75% of the respondents want to use OneUp in their future courses. Furthermore, our analysis shows that OneUp has improved the median grade of students from B+ to A- compared to the same course delivered the previous year without using OneUp.

Keywords:
Cybersecurity education, Gamification, Self-learning, OneUp

1. INTRODUCTION

Students' engagement in course activities is an essential factor to attain the desired learning outcome of a course. Engagement depends on the quality of the course delivery system and the motivation enablers the instructor provides for the students to be proactive in the course activities [9]. Creating an inspiring learning environment is a proven measure an instructor could take to enhance students' motivation and engagement.

Gamification is a growing trend of leveraging game design principles and elements in non-gaming applications to enhance user engagement and motivation. It involves incorporating common game elements, such as points, badges, and leaderboard into the normal process of a non-gaming application. The early gamified applications were mostly for marketing [7]. Later on, gamification got increasingly popular in various fields, including business, health, wellbeing, military and education. Educational gamification tools aid course delivery by utilizing well established game design principles to enhance skill development, routine practice and self-testing. As a result, it helps students to improve their engagement in the course activities. Moreover, students' motivation and course engagement increase if satisfactory game-based elements were added while designing the course [8].

In this article we present a case study on the effectiveness of gamification to enhance the course delivery of a Software Security Testing course. The course was taught at North Carolina A&T State University (NC A&T) in Fall 2019. Following the recent tendency for Cybersecurity courses to be available in the form of distance learning [12], the course was offered as an online course. For the study we used the gamification platform OneUp as a supplementary study aid. OneUp is a gamification learning platform that is utilized to facilitate the process of gamifying academic courses [3]. A previous study has shown the effectiveness of using OneUp to gamify an on campus undergraduate Data Structures course to increase student motivation for out-of-class practice [4]. The study showed that the use of OneUp resulted in increased student engagement as well as reduced failing rate among students. The context of our study differs from the previous one in two aspects: first, the targeted course is a master level course, and second, the course is an online course. We were

especially interested in the impact of using gamification in online courses, since the problem of engaging students in distant education is even bigger. We also wanted to explore how a generic gamification platform, such as OneUp, can be tailored to fit seamlessly into an online course delivery. Thus, the study was guided by the following questions:

Q1: Does gamification encourage online students to practice more?

Q2: Does gamification improve grades in online classes?

Q3: What is students' perception towards the platform and their engagement with it?

The remainder of the paper is organized as follows. Section 2 reviews briefly related work. The research methodology is described in Section 3. Section 4 discusses the principle findings of this study. Finally, Section 5 presents discussion of our findings and concludes the article.

2. RELATED WORK

Applying gamification in Computer Science courses is not a new idea. A number of studies have explored the application of gamification to support student learning and course delivery [2,8]. The game elements most frequently incorporated in gamified learning systems are points, badges and leaderboards. Huotari et al. [7] suggested that these gaming elements are particularly vital to the success of gamified platforms as they represent both the reward and competitive aspects of a learning system. Hakulinen et al. [6] demonstrated that awarding badges in Data Structures and Algorithms course can motivate students to study and to engage in desired learning activities. Their study did not enforce strict course policies, for instance, they had unlimited number of resubmissions for exercises to encourage students to keep trying until they solve the exercises correctly. Sprint and Fox implemented a flipped classroom with team-based gamification of student study choices [10]. They rewarded students for practicing "good" study habits, such as turning in assignments early and retaking quizzes for extra practice and found out that students did make better study choices, but these choices did not lead to higher final exam scores. Dicheva et al [4] described gamifying of a Data Structures course by using badges, leaderboard and virtual currency. The study showed that the

gamifying of the course increased student engagement and reduced failing rates.

There have been only few attempts to gamify learning in Cybersecurity education. Tomcho and colleagues evaluated the effectiveness of gamification for an online military cyber education platform [11]. They applied unique game elements, Cyber Topic Map and Knowledge, Skill, and Ability (KSA) Trees in their experiment. Their study concludes that a careful gamification design and game elements will have a positive impact on motivation and engagement of learners with the platform. Another study applied Catch the Flag (CTF) tournament as a gamification process for cybersecurity courses [6,1]. The results showed that the tournament helped students to reinforce the learned skills and to apply them to specific challenges. Wood used Flipped Learning Adaptive Gamified Simulations (FLAGS) to improve correct first-time answers on hands-on laboratory tasks in cybersecurity distance learning [12]. In the experiment, existing simulation authoring software from the *Serious Factory* company was used. It enabled the employment of five gamification elements: player avatars, realistic environments, narrative context, feedback to answers, and time pressure. Although not statistically significant, the results showed higher scores within the experimental group.

Most of the studies on gamifying Computer Science courses have targeted undergraduate, face-to-face, predominantly programming courses. Differently, we targeted a graduate-level, online Cybersecurity course. Our study is different from the described above cybersecurity-related studies in both the context in which gamification was applied, as well as the used gamification elements. Moreover, published studies report mixed success in the application of gamification in various educational contexts, which requires more empirical evidence. This study contributes to filling this gap by assessing the effectiveness of OneUp-based gamification of an online Cybersecurity course.

3. METHODOLOGY

3.1 Course delivery strategies

In this study, we used the OneUp platform, to gamify the online course “COMP 725 - Software Security Testing”. This graduate level course is offered

only in the Fall semester and has comparatively low enrollment. In the study, we used Fall 2018 class (17 students) as a control group and Fall 2019 class (12 students) as an experimental group. The same instructor taught both classes using the same course materials including assignments and quizzes. All students in the experimental group signed an Informed Consent Form to participate in the study and students' usage of OneUp was voluntary.

The control group used only the course delivery platform Blackboard, which provided access to course modules along with quizzes created by the instructor. The quiz questions were included at the end of the reading material in each module. Our goal in gamifying the course was to encourage student self-study and practicing before taking the quizzes. OneUp supports gamified practicing, so we separated the quizzes from the reading materials, so that the students could first read them (in either Blackboard or OneUp), then practice and self-assess their knowledge in OneUp, and only then take the graded course quizzes in Blackboard. Thus, for the experimental group we introduced the OneUp platform not only for gamifying the course but also as a supplementary mechanism for delivering the course materials. Students were given 4-6 days to complete the reading and practicing. Blackboard quizzes were made visible after the due dates for solving the OneUp serious challenges.

3.2 OneUp platform and gamifying the course

The OneUp gamification platform [3] supports two kinds of quizzes, "warm-up" and "serious" challenges. Warm-up challenges are created for practicing and self-assessment and serious challenges are graded course assessments. OneUp offers various game elements, including avatars, badges, leaderboards, virtual currency, progress bar, etc. It is highly configurable, and the instructor can select the elements to be included in their gamified course.

To prepare the gamified version of the course, for each of the 15 course modules we created their own warm-up and serious challenges in OneUp: 31 warm-up challenges with a total of 170 problems and 15 serious challenges with a total of 134 problems. Further on, we configured the gamification elements for our course. We decided to use experience points (XP), avatars, leaderboard, badges, virtual currency (VC) and learning dashboard. We also

created the gaming rules, according to which students would get their rewards (badges and VC). Below is some information describing our choices.

We allowed the students to select their own avatars from the available list of avatars. In the learning dashboard, each student could see aggregated information about their use of OneUp: their warm-up and serious challenges' scores, experience points, badges and VC collected so far. Badges were given to students in order to motivate them to practice more and we created 6 different kinds of badges. To earn a badge, a student had to satisfy one of the instructor's gaming rules. As soon as a badge was earned, it was displayed on the leaderboard. Most of the badges we created were associated with warm-up challenges. Table 1 shows sample badges used in the course.

Table 1
Sample badge categories used in the course

Badge	Badge name	Earning rule
	First Warm-Up	Score > 75% for the first ever warm-up challenge
	Practice Hero Gold	Complete 15 distinct warm-up challenges
	Super Hero Bronze	Complete 25 distinct warm-up challenges

The other feature we used was virtual currency (VC). We used VC as a reward for solving serious challenges and student's engagement in the course as a whole. Students earned VC for solving problems and could use it to buy a resubmission of assignments. We created earning and spending rules. For example, students must score 90% or above on a serious challenge to get one course buck. But if they scored 100%, they will get 2 course bucks. Students will also get one course buck for practicing 5 consecutive warm-up challenges with a score of 90% or above. When the collected VC reaches 15 course bucks, then students get the chance to spend it in the course shop.

4. RESULTS

4.1 OneUp interaction

Students interaction with the inbuilt game elements such as points, avatars, leaderboards, badges, virtual currency, etc. is discussed below.

Avatars: Students were allowed to select their own personal avatars from an available list. Avatars help students to anonymize their identity and results. We were hoping to see that all students will have their own personal avatar, but surprisingly all students chose not to use a personal avatar.

Virtual Currency: During the course, 117 VC earning transactions were recorded. The course bucks were acquired by satisfying one of the earning rules specified by the instructor. Fig. 1 shows the total VC earned for each module.

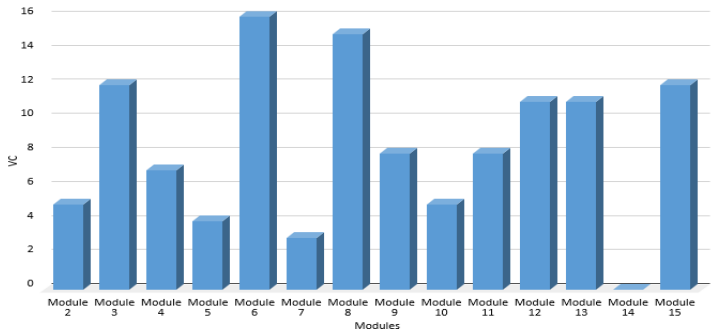

Figure 1: Virtual Currency earned by Module

Badges: We set a total of 6 different kinds of badges for this course and all students participated in the experiment received at least one badge. 67% of the students received 4 and more badges. The most badges have been awarded for a first timer who completed 5 distinct challenges. We divided the badges based on the level of completion of warm-up challenges. 33% of the students completed more than 25 distinct challenges.

4.2. Student performance

Final coursework grades of both the control and experimental groups were evaluated to see the impact of gamifying the course. Figure 2 shows the distribution of final grades. As shown in the figure, the use of OneUp in the course has improved the median grade of students from B+ to A-.

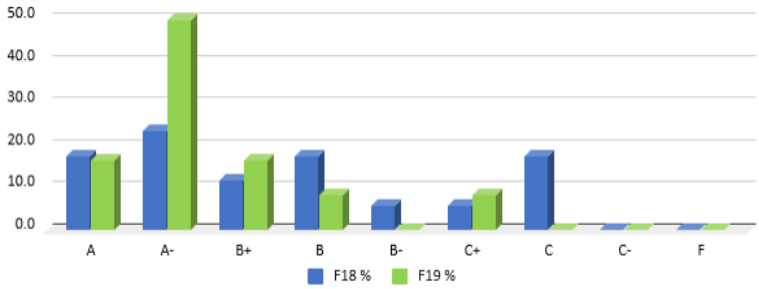

Figure 2: Final Course Grade comparison

4.3 Survey results

A survey questionnaire which contains 27 questions was given to the experimental group at the end of the semester. We used a numeric Likert scale from 1 (strongly disagree) to 5 (Strongly agree) with 3 as a neutral option. This survey helped us in understanding students' point of view towards gamifying a course and what specifically motivated them to engage in this course. Table 3 shows sample questions used in the survey grouped by the following categories: effectiveness of the tool, motivation, and level of engagement. The response for each sample question is shown in Figure 4.

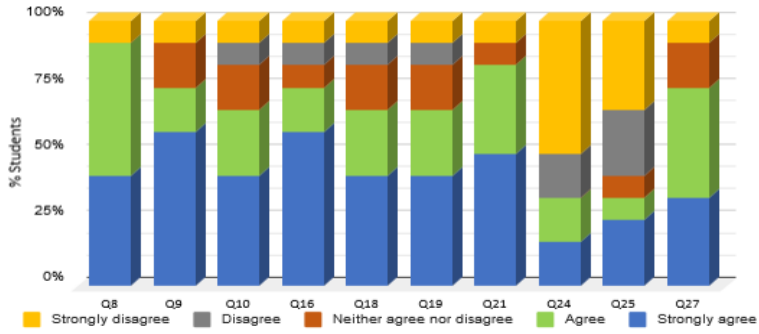

Figure 4: Answers to the sample survey questions.

As shown in the figure, 90% of the students participated in this experiment agreed that OneUp has increased the effectiveness of self-learning and more than 65% of the students agreed that OneUp has helped them to improve their grades. Based on the results we got from the students' feedback, OneUp was considered a useful platform.

Table 3
Sample survey questions by category

No.	Survey question
Q8	I felt more effective with regards to self-learning when using OneUp
Q9	Using OneUp made it easier for me to master course material & prepare for quizzes.
Q10	Using OneUp helped me to improve my grades.
Q16	A desire to boost my grades prompts me to practice in OneUp.
Q18	A desire to get new OneUp badges prompts me to practice in OneUp.
Q19	A desire to get new virtual currency prompts me to practice in OneUp.
Q21	When taking a warm-up challenge in OneUp I put in effort to complete it.
Q24	I do not take very seriously the warm-up challenges in OneUp (R).
Q25	When taking a warm-up challenge I do not pay much attention to my performance.
Q27	I intend to use OneUp if offered in future courses.

A desire to improve grades, earn badges and VC were the motivation for students to practice more. More than 75% of the students considered OneUp challenges seriously and would use the platform if offered in the future. This is one good result to the level of engagement we were expecting to achieve.

5. DISCUSSION AND CONCLUSION

In this study, we investigated the effect of gamifying a cybersecurity course on student's motivation and engagement. We used a graduate Software Security Testing course for this experimental study. We compared a gamified (experimental group) with a non-gamified (control group) where both groups took the online course. Our analysis shows that the OneUp gamification

platform has increased the effectiveness of self-learning and motivation as well as helped to improve the median grade of students who participated in the study.

Since we were the first to offer a gamified course in the department, we were expecting a great enthusiasm in the students. We were also expecting that all students will practice in OneUp in order to get a chance to re-submit assignments. However, some students fail to login and practice for a couple of weeks. Then, we decided to add another benefit - serious challenge points count towards the final grades. This announcement motivated almost all students to login and practice more. We still noticed that some students would only concentrate on solving the serious challenges. These results show that students are motivated to practice if they think it will influence their final grade.

One of the limitations of this study is the small number of participants (12). Having a small number of participating students might make it easier to track their activities and achievements, however makes it difficult for us to understand whether the implemented gamification has improved student motivation to practice or not. For example, in our experiment, some students who didn't score much in OneUp got better final grades. As a future work, we are considering to study the impact of gamification on other computer science courses with a higher number of students.

Following our previous practice, where we used to post on Blackboard course modules, quizzes and assignments every week, we did the same on the OneUp platform - uploaded the course materials on a weekly basis. But doing so constrained the students, since they had only a small number of problems to practice with. This, in turn, might have led to loss of motivation and eagerness for practicing. We believe that if we upload all course materials and resources at the beginning of the semester and have more warm-up challenges, students' motivation could be better than what we achieved now.

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