Comparing the Student Engagement with Two Versions of a Game-based Learning Tool

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Abstract: Research has shown that game-based learning techniques positively impact students' engagement, motivation, and learning outcomes. We performed a study to explore the differences in student engagement with a game-based learning tool implemented on two different platforms: mobile and web-based. We developed two versions of a peer-quizzing game where the students can create quiz questions related to the learning material, which their peers can attempt to answer. The students can create three types of questions: Multiple Choice Questions, True/ False, and short answers. Students from a first-year introductory programming computer class were recruited to evaluate both versions of the game during one academic term (four months) during the Covid-19 pandemic when classes were entirely online. A bonus participation mark of up to five percent of the course was offered to students who posted at least three questions per week. In addition, we collected data about the students' in-game activities for the study duration. The Mann-Whitney U-test results show no significant difference in the engagement between the web and the game's mobile version. However, students posed more questions in the mobile version than in the Web version of the game. On the contrary, students solved more questions in the web version than in the mobile version. We have learned from the study that both game-based learning platforms effectively engage students. We also collected data about the students' experience with the game in a post-study survey. The responses show that both game versions got similar user experience ratings.

Keywords: Game-based Learning, M-learning, Peer-quizzing, Engagement

1. Introduction

The use of technologies in learning and teaching has increased over the last decade and allowed us to explore and improve how we deliver the learning materials. With the availability of various technology platforms, such as web, mobile, virtual, and augmented reality, new ways of presenting learning and evaluation materials are possible (Pedro, Barbosa and Santos, 2018). Gamified and game-based learning tools are used to enhance the learning process further (Grund, 2015). Gamification is the process of using game mechanics and dynamics in non-game contexts (Kapp, 2012). Moreover, game-based solutions pursue a secondary goal of motivating users to engage in target activities (Deterding *et al.*, 2011; Qian and Clark, 2016). Various studies have presented positive results in using both gamified and game-based learning solutions in education (Connolly *et al.*, 2012; Dichev and Dicheva, 2017). Most studies reported that both gamified and game-based learning solutions help motivate and engage the learners and may improve their learning outcomes (Zainuddin *et al.*, 2020).

Mobile learning games are becoming increasingly popular because of how compact and convenient they are. In addition, the sensors generally found in smartphones can be utilized to enhance their apps further. For example, learning apps can use GPS to locate learners and deliver tailored lessons to the context. On the other hand, web-based applications are popular too because of how easy they are to access. The user only needs an up-to-date web browser to use a web application. Web game applications also require fewer computational resources compared to full computer games.

The study reported in this paper explores two versions of a game-based learning tool that encourages the learners to create quiz questions and answers of their own. The learning objectives for both versions of the game are to persuade learners to form high-quality and tricky questions about the learning material, to develop critical thinking skills, and playfully practice for quizzes and exams with their peers. In addition, a question-and-answer bank of student-generated quizzes is built as a by-product, which can be used for class quizzes and exams. Specifically, in this paper, we aim to compare the two versions of the game and find which version is used more actively (i.e., engages the students more) and supports a better learners' experience (using a post-study survey). Our initial findings suggest that the students like both versions of the game; activity-wise, the mobile version had slightly more student-generated quizzes.

2. Background

The recent popularity of game-based learning solutions has influenced researchers to experiment with various approaches (Deterding *et al.*, 2011). Researchers using game-based learning tools have mostly reported positively impacting their implementations (Connolly *et al.*, 2012). Learners like gamified and game-based learning solutions, because of the extra layer of entertainment and excitement added by the mechanics and dynamics of an existing task (Krath, Schürmann and von Korflesch, 2021). Some commonly used game elements in non-game contexts are points, badges, and leader boards. Using these game elements, the hardship of the main task becomes less noticeable because of the rewards and satisfaction playing with the game elements brings. Thus, the learners feel motivated, engaged, and captivated by the system.

The use of game-based learning solutions and the level of engagement varies and depends on the type of platform and the target users (Morschheuser *et al.*, 2017). While game designers try to make their systems as inclusive as possible, the quest for a universal solution is still elusive today. Some designers use artificial intelligence to adapt their systems to match the individual learners' needs (Dalponte Ayastuy, Torres and Fernández, 2021). Mobile phones are among the most popular platforms for both gamified and game-based learning solutions. M-learning has existed for some time (Georgiev, Georgieva and Smrikarov, 2004). Most mobile phones released after 2015 are powerful enough to process rather complex programs. Many mobile applications exist for research that utilizes gamification and games to facilitate behaviour change (Bartel and Hagel, no date; Oyibo *et al.*, 2019; Olagunju, Ogenchuk and Vassileva, 2021).

3. Design and development of the two games

Most students are strongly attached to the Internet and mobile devices because of their popularity and availability (Kirschner and Karpinski, 2010). In addition, online activities increased during the Covid-19 pandemic because most learning institutions closed, and classes were delivered online. Thus, students spent more time on their computers and mobile phones to stay connected with their peers and teachers. To utilize the online learning situation during the pandemic, we have used two versions of the same game-based peer-quizzing application with minor differences in the features: a web and an android mobile application. Details about both versions and their similarities and differences are discussed next.

3.1 An overview of the game

We have developed a peer quizzing game called the Tower of Questions (ToQ) (Kiron *et al.*, 2019). The students play by logging in with their pseudonyms (gamer IDs) and passwords and creating “towers” by posting questions related to the learning material. Other students attack the towers by answering or solving other players' questions. The students can choose from three categories of questions/towers: Multiple Choice Question (MCQ), True/False, and Short Answer (SA). The MCQ and True/False questions are automatically evaluated, whereas the answers to SA need to be reviewed by the creator within one week. If the answer to the question is correct, the tower is “conquered”. All the conquered towers are available for all players to view and study, by inspecting the questions and answers.

There is a points system in the game called the “gem bank”. The gem bank has a finite number of gems from which a small portion is awarded to the player when they create towers. When a player attacks a tower successfully, they get a portion of the gems initially awarded to the tower’s creator. For example, initially, the gem bank had one hundred gems. When a player builds a tower by asking a question, they will receive ten gems from the gem bank. If other player attacks and conquers the tower, they would receive four gems from the ten gems awarded to the creator as a reward for conquering the tower. The player who created the tower will keep the remaining six gems. Because each new tower takes away 10 gems from the bank, the more questions are created, the fewer gems remain in the gem bank. If there are no gems left in the bank, no further questions can be posted, and no new towers can be created. Thus, the number of gems available in the bank controls the number of questions created by the group of players, as desired by the instructor. Screenshots from the web-based and mobile versions of the game are provided side by side in Figures 1-6.

Table 1: Screenshots from both versions of the game

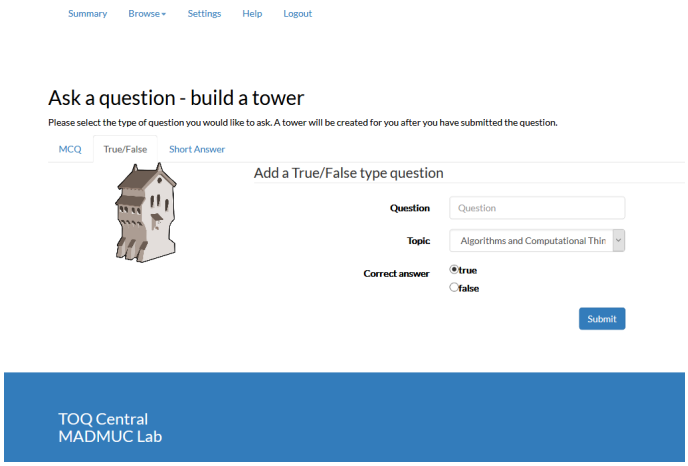

Figure 1: Building a new tower in the web game

Figure 2: Building a new tower in the mobile game

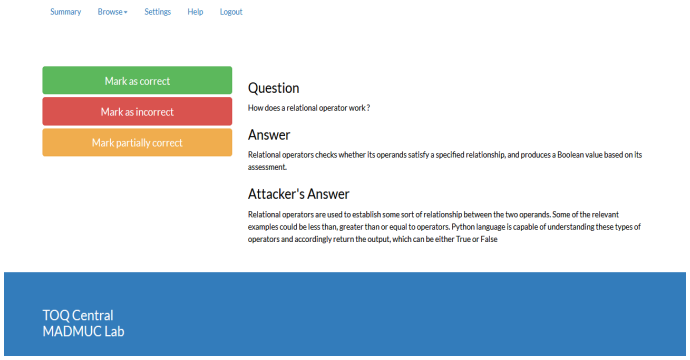

Figure 3: Viewing a short answer from the creator's perspective

Figure 4: Viewing a question and the answer

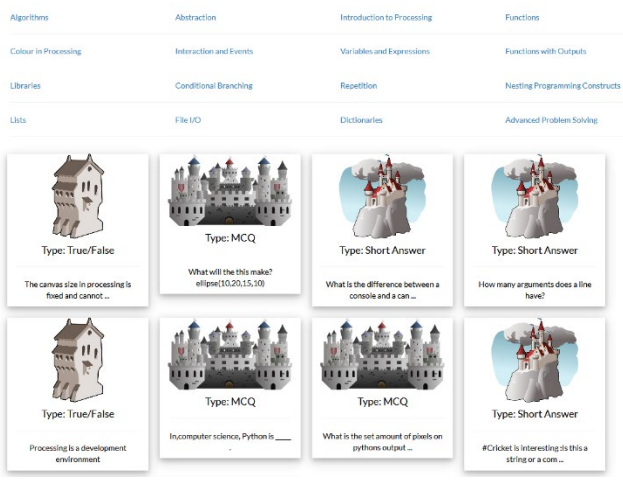

Figure 5: The conquered towers or answered questions in the web game

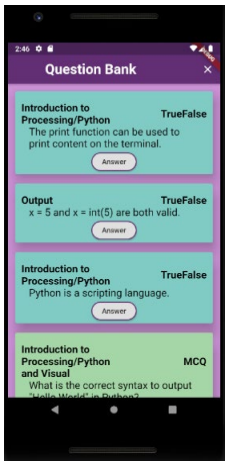

Figure 6: The conquered towers or answered questions in the mobile game

3.2 Similarities and differences

Although both versions of the application share most of the learning and game features, there are some differences. Similarity-wise both versions of the game have a gem bank, but do not have a leader board; both versions limit the number of questions the students can ask, and maintain player anonymity (via aliases) in the game. Regarding the differences, the mobile version does not have a flagging feature. The flagging feature is used in the web version of the game to allow players to report spam, duplicate quizzes, and low-quality or trivial questions. The other differences in the mobile version are in the user interface layout. The aesthetics of the mobile version had to be adjusted to fit the size of the screen. The web version was developed and tested before the mobile version.

4. User Study, data analysis and results

This section presents the design of our study to determine which version of the game is more effective in engaging students during the pandemic and to discuss the result of the data analysis performed. One hundred twenty-one participants from our university's first-year programming language course CMPT 145 were divided into two groups: 75 in group W (used web version) and 46 in group A (used application version). The reason for having few participants in group A is that the application version of the ToQ game is only available on Android devices. Hence, participants with iPhones or other devices had to use the web version of the game.

The study was approved by the Behavioural Research Ethics committee of our University and lasted for an entire academic semester (four months), from January to April 2021. At the beginning of the study, the participants completed a pre-study questionnaire and the end of the semester – a post-study questionnaire. Participants in group W collectively created 1328 towers throughout the semester, while group A created 961 towers.

The independent variable in our study is the game version used by each experimental group. The dependent variables are the engagement metrics: the number of active users per week, the number of towers created each week, and the number of towers successfully attacked by the active users each week. For all results, we considered active users to be anyone who logged in and created at least one tower in the system in a week. The descriptive statistic indicates differences between the application and the web version of the game. Mann Whitney U-test was used to test the statistical significance of the results.

The null and alternative hypotheses for dependent variables are as follows:
H_0: There is no difference between the number of active users (towers created and solved) in groups A and W.
H_1: There is a difference between the number of active users (towers created and solved) in the A and W groups.

The results (the values of the dependent variables) are presented below:

Active users: Figure 7 shows the percentage of active users in a week by the total number of participants in a group. The graph shows the percentage of active users in both game versions each week for 12 weeks of the full term. As more users participated in group W, the graph shows that the number of active users was slightly higher in the W group in 8 out of the 12 weeks. In three of the 12 weeks (excluding the week of Feb 14-20, the spring break), the A group had a higher percentage of active users. The Mann-Whitney U test result shown in Figure 8 indicates that the difference between the two groups is not significant (H_0 confirmed).

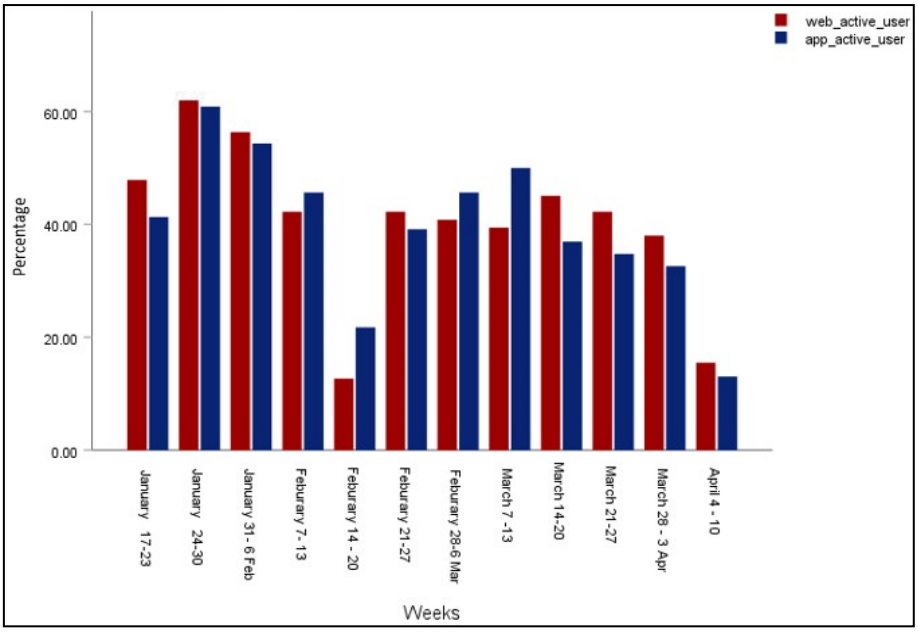

Figure 7: Number of active users per week in each group (App and Web)

Test Summary	
Mann-Whitney U	78.000
Asymptotic Sig.(2-sided test)	.729
Exact Sig.(2-sided test)	.755

Figure 8: Test summary of active users per week in both groups

Towers created: Figure 9 illustrates that the mean number of questions posted (towers created) by the active users each week in the App version is consistently higher than that of the Web version of the game. The Mann-Whitney U test result shown in Figure 10 shows that the difference is significant (H_1 confirmed).

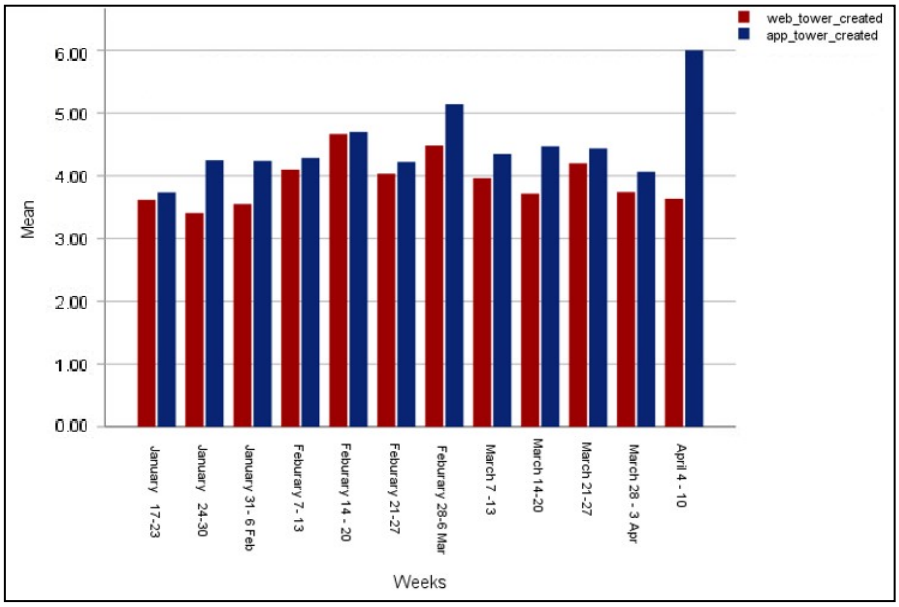

Figure 9: The number of towers created by active users in both versions per week.

Test Summary	
Mann-Whitney U	25.000
Asymptotic Sig.(2-sided test)	.007
Exact Sig.(2-sided test)	.006

Figure 10: Test summary of towers created by active users

Towers Solved: The results for the number of towers (questions) conquered (solved) only include the number of users who successfully attacked the towers, and it does not include the users who tried to answer the question but failed. The graph illustrates that the participants in the A group were enthusiastically solving the question towers before the reading week, but their participation dropped significantly after the reading week. After the spring break (Feb 14-20), the participants in group W became more active in solving questions, and only in two weeks did the participation of group A come close to that of group W. The result of the Mann-Whitey U test shown in Figure 12 confirms that the difference is significant (H_1 confirmed).

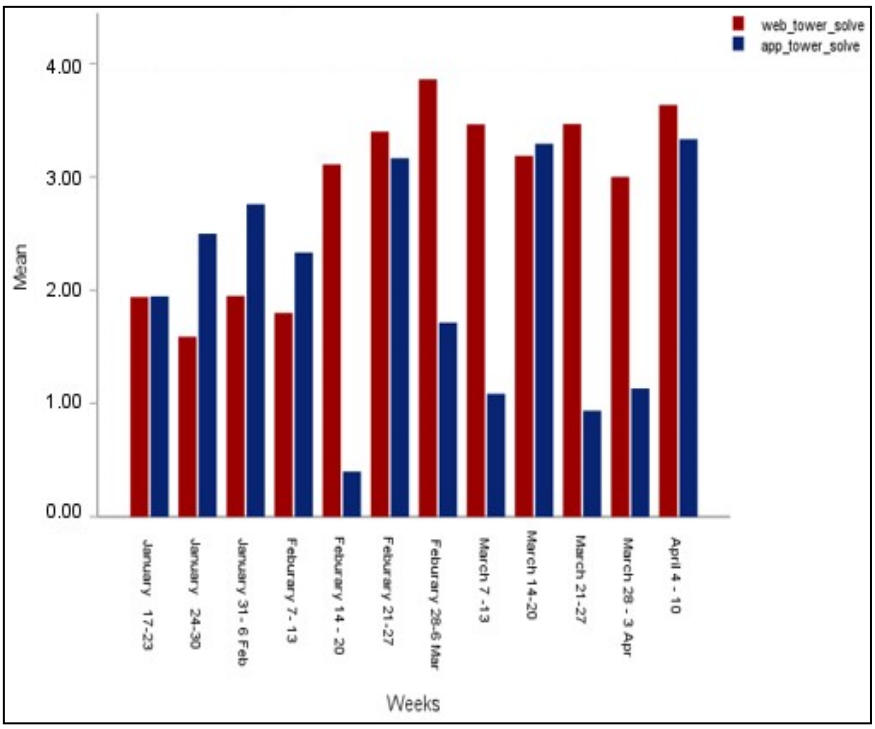

Figure 11: Tower solved by active users in both versions each week.

Test Summary	
Mann-Whitney U	108.000
Asymptotic Sig.(2-sided test)	.038
Exact Sig.(2-sided test)	.039

Figure 12: Test summary of tower solved by active users

User Experience: In the post-survey questionnaire, we asked the participants to rate their game experience with the game on a scale of one to five, with one being the least and five being the highest satisfaction rating on the Likert scale. Forty percent (20 participants) of the 46 students in the A group participated in the post-survey questionnaire. The average satisfaction rating of the App version was 3.65 out of 5. On the other hand, 53% (38 participants) of the group W participants completed the post-survey questionnaire, and their average satisfaction rating was 3.86 out of 5.

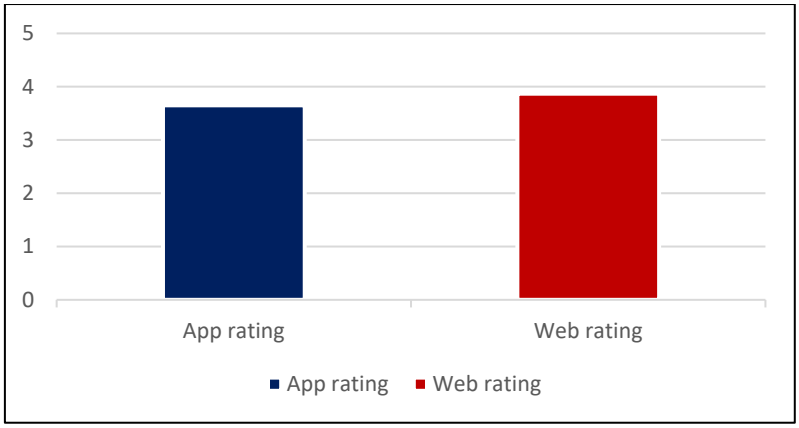

Figure 13: User rating for both versions.

4.1 Results Report

To check the normality of the data, the Shapiro-Wilk test was performed. We have presented the results using two methods in SPSS: the Mann-Whitney U-test and the Independent Sample T-test.

4.1.1 Active Users

The total number of users who actively participated in our study was 117. Of the total users, 60.68% of participants signed up for group W, whereas 40.38% actively participated in the study. For group A, 39.31% (46) students were recruited, and the participants who actively participated were 39.67%. The statistics show nuance in the average active users in both versions. This result is also explained using a Mann-Whitney U test in SPSS. The test evaluates the difference between the engagement of the active users in both groups. Results analysis indicates no significant difference between the active users in both groups. The mean number of active users for group W (M = 40.3) is slightly higher than the mean of the number of active users in group A (M = 39.6), but the Mann-Whitney test indicated that this difference is not statistically significant, U = 78, z = .347, p > 0.05 (Figure 8). The mean difference of active users is by chance because the significance value p is greater than 0.05, thus confirming the null hypothesis H_0.

We also performed an independent sample T-test to test if Group A and W have a statistically significantly different number of active users. Results show that Group A (SD= .78) has more active users statistically than group W (SD = 1.34). Additionally, the assumptions of homogeneity of variances were tested and satisfied via Levene's F-test, F (22) = 0.80, p = 0.378. The independent samples T-test was associated with no statistically significant effect, t (22) = 0.832, p = 0.414. Cohen's D was estimated at 0.340, a small effect size based on Cohen's (1992) guidelines. Thus, no difference has been found between the number of active users in Group A and W. The statistical analysis confirms that there is no difference between both groups, so we retain the null hypothesis (H_0).

4.1.2 Towers created

We can show that more towers, on average, were created by an active user in group A of the game. We conducted a Mann-Whitney U test to check the difference between the number of towers created in groups A and W. The mean and median for towers created by active users is higher in group A compared to group W. The test analysis shows a significant difference between the number of towers created by active users in groups A and W. The median of towers created by the active users for group A (MD = 431) is higher than in group W (MD = 385), and the Mann-Whitney test indicated that this difference is statistically significant, U = 25, z = -2.714, p < 0.05 (Figure 10). These results show a substantial difference between the tower created in both groups. Also, the two-tail significance value is less than 0.05, which means we can reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). The report shows that the mean of towers created in the mobile version (M = 449) is higher than the mean of towers created in the web version (M= 392). These results show that the participants preferred to post questions using the application version of the ToQ. The post-study questionnaire contained the question "Which feature(s) did you like in the game?". The data shows that 17 out of 20 participants preferred creating a question in the mobile version. The report shows that participants prefer to use the mobile version while posting a new question.

Moreover, the results of an independent sample T-test show that Group A has higher mean towers created by active users (M = 8.83, SD= 1.47) than group W (M = 5.80, SD = 2.68). Additionally, the assumptions of homogeneity of variances were tested and satisfied via Levene's F-test, F (22) = 1.43, p = 0.244. The independent samples T-test was associated with a statistically significant effect, t (22) = 3.42, p = 0.002. Thus, there is a difference between the number of towers created by active users in Group A, and W. Cohen's D was estimated at 1.39, which is a considerable effect size based on Cohen's (1992) guidelines.

4.1.3 Towers solved

We investigated the results for solving towers by active users in both groups each week. Figure 11 shows the active users' mean of successfully solving the question towers. We had not included the data when users tried to solve the question but were unsuccessful. The result shows that, on average, the participants in group W solved 34.48% more questions than group A throughout the term. A Mann-Whitney U test is conducted to determine whether there is a significant difference between the towers solved by active users every week in the A and W groups of the game. Results of that analysis indicated a significant difference between the tower solved by active users of both groups. The number of towers solved by the active user in group W (MD = 314) is higher than the tower solved by active users in group A (MD = 214). The Mann Whitney test indicated that this difference is statistically significant, U = 108, z = 2.078, p < 0.05 (Figure 12). Furthermore, we accept the alternative and reject the null hypothesis because the two-tail significance value is less than 0.05 (Figure 12). The statistical report shows that the mean of the number of towers solved is higher in the web version (M = 286.7) than in the mobile version (M = 205.05). Lastly, the T-test result shows that the active users in Group A have solved a smaller number of towers (M = 5.85, SD= 1.99) compared to those in group W (M = 8.67, SD = 1.66). Additionally, the assumptions of homogeneity of variances were tested and satisfied via Levene's F-test, F (22) = 0.607, p = 0.444. The independent samples T-test was associated with a statistically significant effect, t (22) = -3.76, p < 0.001. Thus, there is a difference between the number of towers created by active users in Group A, and W. Cohen's D was estimated at 1.53, which is a considerable effect size based on Cohen's (1992) guidelines.

4.1.4 User Experience

From our post-study questionnaire, we found that the participants like to answer the questions more in the web version of the game than in the mobile app version. When asked, "Which feature(s) did you like in the game?", those in the web-version group responded, "Attacking towers". The mean and median for towers solved by active users are higher in group W than in group A and the statistical test report shows that participants prefer to use the web version while solving the question over the mobile version. The reason for using the web version could be that the students can see and understand the problem better when using the web version. For example, if a student posts a lengthy MCQ question, it is easy to read the question and compare the options in the web version. In the mobile version, the students must remember all choices to compare them, which could result in a cognitive overload for the student. Another reason might be that when answering questions, it was easier to consult the course materials on the web than using an app.

Furthermore, the students rated the version of the game they used, but unfortunately, only a small number of participants completed the questionnaire. The statistic shows that 43.47% of participants from group A and 53.52% of users from group W rated the game. The average rating for the application version is 3.65, whereas for the web version, 3.86 out of 5 (Figure 13). Most of the participants in our study rated both versions of the game with an average of above 3.5 on a scale of 5. This result also shows that both versions of the game were rated favourably.

5. Discussion and conclusion

In this paper, we investigated the effectiveness of application-based and web-based versions of the educational game Tower of Question (ToQ) (Kiron and Vassileva, 2018) in engaging students by evaluating the two versions in parallel within one class and comparing the results from both versions. The result shows that there is no significant difference between both versions of the game. Both versions have almost the same functionalities, such as posting a new question, gaining points (gems), and solving the questions posted by other users in the system.

The only differences between the two versions were in the interface design, the aesthetics, the implementation platform, and the presence flagging feature in the web version. The application version had a more vibrant colour than the web version. We employed a quantitative approach to collect data to determine which version

is more effective in game-based learning by using the Mann-Whitney U test to match the perspective of this study. The data analysis provided the answer to the research question, "Is there a difference between the effectiveness of the two versions in engaging students and if there is, which version is more effective?". The evaluation of the game-based tools shows no significant difference between the two versions in the number of active users (one of the engagement measures used). However, there were significant differences between the student's engagement in the two-game versions in terms of creating questions and answering questions. The students were significantly more engaged in creating new questions (towers) in the mobile application version and more engaged in answering questions (attacking towers) in the web version. Thus, in both implementation platforms, the game can engage students and increase learning through practice. Both versions of game-based learning are helpful by providing value to the user and helping them achieve their goal of practicing their course materials. Other research also supports these findings, such as business/ marketing (Ding, Guan and Yu, 2017; Zakaria *et al.*, 2018), education/learning (Barata *et al.*, 2013; Ding, Er and Orey, 2018; Rachels and Rockinson-Szapkiw, 2018), health/work out (Calle-Bustos *et al.*, 2017; Kostenius, Hallberg and Lindqvist, 2018; Rajani, Mastellos and Filippidis, 2021). One recommendation resulting from our work for designers would be to create and maintain two versions (both web-based and mobile app) of educational games so students can use both simultaneously to increase engagement in different activities.

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