

**COMPARING STUDENT ENGAGEMENT WITH TWO VERSIONS OF
THE GAME-BASED LEARNING TOOLS: MOBILE AND WEB**

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By

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ABSTRACT

Game-Based Learning is useful in teaching because it encourages students to discuss, engage, and collaborate in groups. Research has shown that game-based learning techniques positively impact student engagement, motivation, and learning abilities. Studies explore the impact of game-based learning on different platforms. The result of the studies shows that game-based learning has a positive impact on students when used on Mobile or Web. Hence, studies need to identify which platform is more engaging and effective for the students. This research investigated the difference in student engagement with a game-based learning tool implemented on mobile and web-based platforms. 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 game allows the students to create three different types of questions: Multiple Choice Questions, True/False, and Short Answers. Students from a first-year introductory programming computer class were recruited as participants to evaluate both versions of the game during one academic term (four months). A bonus participation mark of up to five percent of the course was offered to students who posted at least three questions per week. We collected data about the students' engagement in in-game activities for the duration of the study. The results show no significant difference in the engagement between the web and the mobile version of the game. However, the number of quizzes asked in the mobile app version and web versions varied in quantity. Students posted more questions in the mobile-based version as compared to the Web version of the game. On the contrary, students solved more questions in the web version than in the App version. We have learned from the study that both game-based learning platforms effectively engage students. In a pre-study survey, we collected the students' demographic data and their gaming experience and their reflection on the experience with the game with respect to usability, enjoyment, and learning, in a post-study survey. The data from the post-survey questionnaire shows that both versions of the game show similar user experience ratings.

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DEDICATION

This work is dedicated to Allah Almighty.

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CHAPTER 1: INTRODUCTION

With the rapid advancement and development of computer-based educational games, the opportunities for instruction and learning have grown. Computer games help develop higher-order thinking skills in users, e.g., critical thinking, exploring, assessments, analyzing and explanation [62]. Game-based learning approaches engage users in various fields, such as education [17, 28, 36], health [33, 34, 35, 30], e-commerce [56, 38], etc. Game-based learning can motivate and engage students in discovering new concepts, practising problem-solving, and developing skills in fun and exciting ways. This thesis will use the following definitions of terms that occur in the literature:

- **Gamification:**

The addition of game-like-elements, also called game mechanics, in non-game settings [5], especially as a technique to encourage engagement with a system.

- **Game-based learning:**

The design of learning activities that are intrinsically game-like. GBL is a teaching approach that uses the power of games to establish and support learning objectives.

- **Learning Engagement:**

“Learner engagement relates to the degree of attention, curiosity, interest, and passion that students show when they are learning or being taught, which extends to the level of motivation when they learn and progress in their education” [70].

- **M-learning or Mobile learning:**

“M-learning or mobile learning is learning across multiple contexts using personal electronic devices” [71].

Game-based learning (GBL) has been used successfully for many years and can positively impact learners. Studies have shown that game-based learning can be very effective in increasing student

engagement in learning activities [29], their learning perceptions and their learning experience [54]. Furthermore, GBL may reduce students' participation anxiety, increase their motivation to understand the course material and improve their academic performance. Moreover, game-based learning approaches may help participants control negative behavioural patterns [58] and develop and improve healthy and beneficial habits [30].

The students' active engagement with the course material is one of the main possible advantages of game-based learning. Actively engaging with learning materials could be difficult for students, especially in an environment full of distractions such as ambient noise, rumination, or social media. However, a GBL environment can encourage students to continue actively engaging in learning by adding game elements such as points, badges, rank, accomplishments, and self-expression. Thus, the GBL system can help keep students involved in fun ways, encouraging them to continue using, interacting, and engaging with the system. For example, game-based learning can allow students to post and discuss inquiries/ questions based on their conceptual structures of the knowledge gained in class.

GBL can drive students to engage in an active learning environment. Students can determine how they want their games to conclude based on the rules and prizes provided by the GBL system [49]. For example, points are the prizes, and the rules are the boundaries to make the game enjoyable and challenging. GBL can allow students to evaluate one another playfully and help them focus on the game goals rather than get distracted. This method also provides more opportunities for understanding the specifics, conversations, opinions and preparing for future assessments.

GBL can be delivered in various platforms such as in class, web, and mobile apps, but all platforms can help to achieve the primary goal. Research shows that game-based learning apps increase student interest by making learning tasks exciting and challenging. Furthermore, research shows that game-based learning apps positively impact students' learning performance [59] and increase their engagement to play and learn [60]. Also, research indicates that GBL websites can also help to improve students' learning experience by encouraging the expression of opinions and discussion. As a result, it can stimulate students to actively participate [62], practice and increase their learning performance [61]. Research on web and app platforms in GBL shows positive results and attitudes toward learning.

To contribute to ongoing research in exploring and evaluating the potential of GBL on different platforms, a peer-quizzing game called ToQ (Tower of Questions) was designed and developed in our lab [47, 49]. We implemented it on two platforms: web and mobile. The game uses the mechanics of Tower Defence Games, where students create towers by posting questions and attack towers by answering them correctly. The students can earn points for posting and answering questions which encourages them to participate actively. The web version of the game was evaluated in studies with first-year university students in previous years. It was found that game-based learning on a web platform is beneficial for the students to practice their course material and is a good learning platform [47]. So, the question arises which platform is more engaging and effective for the students: the web or a mobile one?

This MSc thesis research involved creating a mobile application version of the game and comparing the students' engagement with the mobile app version and with the web version regarding the effectiveness of engaging students in the context of a first-year introductory programming class.

Overview of Thesis

The thesis is organized into six chapters in the following way:

Chapter 1: Introduction: Introduces the thesis.

Chapter 2: Research Background and Related Work: This chapter explains game-based learning. It discusses student involvement with GBL systems and the benefits and drawbacks of GBL systems. It includes the necessary background of GBL using different platforms.

Chapter 3: Game Design: This chapter presents a detailed explanation of the ToQ game basics and the reward distribution in the game. This chapter presents the game rules on how to create and attack towers. Also, it presents the implementation and components of the mobile application. Finally, this chapter discusses the design choices for the framework used to develop the mobile application, the libraries, and the cloud platform.

Chapter 4: Method: This chapter describes the methodology of the experiment. It explains how the study is conducted and executed. In this chapter, I discuss the demographics of the participants, the number of participants, the experiment duration, and the location of the study. It also explains the

grouping of the participants in the test group and control group. Finally, it contains the details of the ethical approval and information about the questionnaires used in the study.

Chapter 5: Results and Data Analysis: This chapter presents the experimental results after comparing two game versions with statistical analysis, where I explain the result statistics using different tests. Finally, it includes an analysis of the user feedback from the post questionnaire.

Chapter 6: Conclusion and Discussion: This chapter discusses and summarizes the results presented in the thesis. It also includes limitations and the future directions of the research.

CHAPTER 2: RESEARCH BACKGROUND AND RELATED WORKS

This chapter overviews existing research in game-based learning. It discusses the pros and cons of game-based learning and the use of game-based learning on different computer platforms.

2.1 Game-based learning

The game-based learning method uses game techniques, thinking, and mechanics to enhance non-game contexts [5]. GBL methods have been getting more attention from researchers over the past few years. As a result, GBL has been applied more frequently in educational practices and shows a positive learning impact on students. Because the GBL method involves a distinctive way of presenting learning materials, it can significantly help improve students' learning performance [44] by developing their interest and increasing their engagement in the learning task. Two types of outcomes can be achieved by applying GBL in a system. One is the experiential outcome related to user perceptions, skills, knowledge, opinions, and viewpoints. The other is the instrumental outcome related to correlational educational outcomes such as increased student involvement, retention and learning performance [44]. Research indicates that GBL systems can motivate the students to participate more in the learning activities and show positive instrumental outcomes, such as learning performance and engagement with the learning materials [29, 24, 20, 12, 54].

2.2 Game-based learning and student involvement

As already mentioned, GBL systems can help increase students' engagement with the learning materials, facilitate active learning, and increase motivation in the students [23]. The GBL paradigm can be applied in both computer- and classroom-based learning settings by introducing various game components in the learning activities, including points, badges, feedback, leaderboards, and levels, to make the learning engaging and motivating for the students. Several studies analyze the effectiveness of GBL settings and systems in improving learning attitudes and achievements. For instance, it was shown that the nature of game-based learning encourages students to participate and learn from the GBL system, which results in improving the students' learning attitudes [64]. Students in GBL settings contributed more to learning activities. They had

an improved learning experience, as a GBL setting often motivate students more than a non-gamified one [65, 66]. For example, Lopez-Fernandez et al. (2021) conducted a study where they divided half of the students to learn from the traditional lecture and half of them to learn from a GBL. The result showed that not only GBL was as effective as the traditional method, but it also increased student motivation to learn. The majority of the students in the study preferred the GBL approach over the traditional method [65]. Furthermore, the GBL system encourages students to maintain high participation, active learning, and engagement with the course materials [67, 68]. In short, game-based learning used in the educational system can considerably improve students' active learning, participation, and engagement with the course materials.

A game-based learning system helps improve the learning experience by encouraging students to engage more with the system. Davidson et al. found that after implementing GBL mechanisms, the students' grades can substantially improve because the students are more engaged in practicing the course activities in the system [25]. Another study [23] shows that students were encouraged to pursue more difficult challenges through the courses designed in the GBL system compared to traditional study settings. The result of this study showed that students who used GBL systems provided better ideas than others [23].

GBL can be used with the game components to improve student involvement with the course materials. Barata et al. [17] added game mechanics to a MSc Information System and Computer Engineering course activities. The participants attended live theoretical lectures and then engaged in discussion, course activities and complete course assignments in virtual learning environment. As students performed course activities, they earned points and badges. The students could track their performance using the leaderboard and progress level. The researchers observed more student engagement with the materials in the GBL system than in the non-GBL system [17]. Research studies show that through the GBL environment, we can promote the commitment and accomplishment of students in learning.

2.3 Benefits of game-based learning

Game-based learning has been broadly applied in many fields, for example, business/marketing [56, 38], education/learning [24, 17, 28, 36], health/exercise [33, 34, 35, 30]. The research shows that GBL helps produce constructive experiential outcomes, including behavioural, psychological, and motivational affordance, and benefits the user [7] by allowing them to practice the course

materials. Research shows that GBL positively impacts students. GBL can build the students' engagement with the course materials, improves their accomplishment, inspiration [64], and positively impacts students' performance [8, 10] and feelings of achievement [6]. Studies show students can get less anxious [54, 1] while participating in a GBL environment compared to a traditional learning environment. For example, in a linguistic class, participants can practice speaking English language in the GBL environment more confidently and feel less anxious than speaking English in class [1]. GBL system leads to increased student participation and contribution in class, which is particularly related to improving their performance [11, 47].

Furthermore, GBL can also benefit educators. GBL systems permit instructors to participate in the system's functioning. GBL allows instructors to ask questions, such as in Kahoot, in the system depending on the students' degree of information, accomplish learning in different areas, select the proper game mechanics, and use competitions to advance valuable practices and give feedback and rewards. [9]. The game component, like the feedback feature in a GBL environment, can influence the students to work hard, improve their confidence and motivate them to perform better.

Students who participate in a GBL setting can benefit from an improved comprehension of the subject and satisfaction than those who use the non-game-based learning setting. For example, in the health sector, GBL systems are used to help people fight obesity [33], to help prevent diabetes by developing healthy nutrition habits [34], to prevent drugs and smoking addictions or motivating to quit [30], and to help hearing impaired by speech training [37]. Language learning is another area where GBL systems have been extensively used. Not only does game-based learning impact students positively [28, 36], but it can also enhance the capacity of disabled students to participate in speech training programs [37]. In short, using GBL systems can be beneficial in engaging students in any field.

2.4 Drawbacks of game-based learning

Not all findings show positive outcomes of game-based learning. Participating in GBL for an extended period can sometimes negatively affect the students' experiential and instrumental outcomes [12]. Students' engagement with the game-based learning activities often depends on their familiarity with the game environment. For instance, if a student frequently plays a game, they will understand, perform, and engage better than the other students, who are less familiar with

the game. Secondly, the game features may become too entertaining and may divert students' attention from the course material [11] and negatively affect their grades.

Furthermore, some students have strong negative sentiments about the use of game components such as leaderboards because they are competition-averse, comparing with others may impact their self-esteem and affect their intrinsic motivation which may ultimately affect students' learning performance [13, 15].

2.5 Game-based learning using the web, mobile and classroom

There is a wide range of game-based learning environments: from classroom-based (not requiring any computers) to stand-alone computer-based environments (e.g., combat games using flight simulators or games involving diagnosis or treatment challenging cases for nurse- and medical doctor training using patient case simulators), to the web-based or mobile-based educational games, and gamified learning environments.

Numerous studies have targeted the GBL techniques used in different learning environments such as in-class exercises, web, and mobile application game-based learning. When used as an in-class exercise, the research shows a positive impact of game-based learning methods and components on students' intrinsic motivation and social relatedness [12, 20]. Sixty-three percent of studies described a positive effect on student motivation because of game-based learning systems [11, 14, 17, 22].

A study involving a web-based game revealed that students acquiring information through game-based learning show a superior comprehension of the subject when contrasted with the students' procuring information through nongame-based learning [8]. Some examples of web-based GBL systems are Kahoot, Gimkit, Blooket, Quizizz, and Quizlet. Research shows that both the web and app versions of Kahoot have a positive effect on the instructor's and learners' learning performance, attitude, and perceptions. The study did not compare the different versions, such as web version or app version, of the software [55]. Other examples are Gimkit, which allows the students to participate and compete against each other [69], and Quizizz, which permits users to contribute information on an assortment of topics by answering questions [19]. Many studies show that students engage more in discussion when they use a web game-based learning system [23]. Game mechanics, such as badges, points, leaderboards, and levels, give feedback and encouragement to students [11] and help support students to rehearse and increase engagement [21]

which is a vital component of game-based learning [22]. Table 2.1 presents a classification of the different studies found in the literature that use game-based learning systems in different domains, educational levels, and platforms. Most of the studies show a positive impact on the students and instructors.

The mobile smartphone is now a standard device used in both developing and developed countries in every area of life. Even before COVID-19, there was high adoption of smartphones as educational technology and a rich market of mobile apps for learning; however, there has been an exceptional surge in the use of mobile educational apps since COVID-19 [27]. Due to the lockdowns, there was a massive shift to online education. Students started learning more through web-based and mobile devices, which provide another platform to access learning content. Mobile learning allows a wider opportunity to educate and learn in different contexts and is less expensive since it does not require expensive hardware. Mobile learning can be enabled in different ways, including learning using a mobile app, mobile webpage, or game-based mobile applications. Both students and teachers can consider mobile learning more engaging than learning on other platforms [1, 2], because it allows for different learning methods in education that use a wider range of contexts (learning environments). For example, learning can happen at home, outside during a field trip, in a museum, or in the library, as well as in the classroom. Research has shown more learning benefits for the students using mobile game-based learning than for those who have been involved in conventional face-to-face education for the same length of time [29]. Two studies show that game-based learning mobile applications can positively influence the self-adequacy and motivation of the user [30, 42]. A game component in the mobile learning environment is linked to increasing students' involvement by engaging them with the system and increasing their efficiency and motivation to achieve their objectives and learning task. For example, Wijers et al. [40] have developed a Math Mobile application where students play with the GPS receiver. The purpose of the experiment is to help students learn about mathematical principles as demonstrated in the real world [40]. The result showed that the study participants were exceptionally motivated and engage with mobile game-based learning [40]. Mobile game-based learning can help a student learn the necessary material and develop positive ideas by actively engaging with the learning app.

Table 2.1: Categorization of surveyed literature.

Paper	Gamified/ game-based	Learning Domain (subject)	Educational level	Platform (Class, mobile, web)	Game environment	Multi-Player (Competitive, collaborative, both)	Summary
Barata [17]	Gamified	College course	College students	class	Individual		Positive impact on students' learning experience.
Calle-Bustos [34]	Game	Health	Diabetic children	Mobile	Single		Game is used to teach diabetes children about the content of the food (positive result).
Chen [23]	Gamification	Improve reading	Elementary school	Web	group	collaborative	Gamification increases user engagement and achievement
Costa [60]	Game-based learning	Science	School	Mobile+ Web			The game helps promote the students' interest and engagement and positive opinions from the teachers
Ding [56]	Game-based learning	Finance class	Tertiary education	Online	Individual		

Rajani [30]	Gamified	Health/ Quit smoking	18 years or older	Mobile	Single		The gamified app motivates users to quit smoking
Zakaria [38]	Game-based	Economics/ social science	University first-year students	Mobile	Single		Game-based learning promotes engagement and learning in user
Wijers [40]	Game-based learning	maths	12-14 years of student/ secondary school	Mobile	Single		Game-based learning motivates the students to understand the concept better.
Hamari [7]		Psychological/behavioural					Examines the current state of the gamification and points out the gaps
Zafar et al. [8]	Game-based	Computer network program	Community college	web	single		Used a maze game as gamification. Students understand the course better after using the software
González et al [33]	Gamified	health	Childs 8-12 years	mobile	single		Gamification is used to control obesity in children
Kostenius [35]	Gamification	Health	10-12 years old students	physical			Gamification is used to promote physical

							activity and learning among schoolchildren.
Rachels [28]	Gamification	language	3 rd and 4 th -grade students	Web and mobile	single		Gamification can enhance the language learning skills of students.
Liu [37]	Gamification	Health/ hearing impaired	0-6 years children	Software and Hardware	Single		Gamification helps in speech training for hearing-impaired children.
Zhao [54]	Gamified/educational app	Accounting course	University student	Class		Multi	Used the quiz app in the university accounting class and report a positive impact on the learning experience.
Hanus [12]	Gamified		University students	Class	single		The gamified university course is used to understand the effect of gamification on the students' intrinsic motivation.
Sailer [20]	Gamified	Educational science program	University students	web	single		A positive effect of gamified activities on intrinsic motivation.

Chen [23]	Gamification	Improve reading	Elementary school	web	group	collaborative	Gamification increases the user engagement
Vesselinov [29]	Game-based	Language learning	College students	both	single		Game-based learning effectively increases the motivation of the participant

2.6 Summary

According to the literature, game-based learning can effectively engage and motivate students in learning activities using any platform, such as web, mobile or in-class activities. Game-based learning is effective if it is used in the right environment. It can have no effect or a negative effect on the learner if it does not perform accurately and reliably. The COVID-19 pandemic changed the situation dramatically, and so far, no study has compared web and mobile platforms regarding the effectiveness of educational game-based learning in remote study contexts due to the COVID-19 pandemic. The objective of this thesis is to find out whether the mobile-based version or the web-based version of game-based learning was more effective in engaging a sample of students during the lockdown. To achieve this, I implemented a mobile version of a game-based learning environment and carried out a study using students in a first-year computer science course at the University of Saskatchewan as participants to compare the effectiveness of a web-based and mobile version of the game during the pandemic lockdown when classes were done online. During the pandemic time, when students were studying from home, it was challenging for them to concentrate on and engage themselves with the learning activities. So, the GBL system played an important role in helping the students interact with each other and engage in learning in a collaborative and competitive way. The next chapter presents the design of the mobile version of the ToQ game; Chapter 4 presents the design of the study used to test the mobile version of the ToQ game in comparison to the web-based version.

CHAPTER 3: GAME DESIGN

The previous chapter presents a review of prior research on the effectiveness of game-based learning in the field of education. This section describes the ToQ game, which I have implemented on a mobile platform to understand the effectiveness of game-based learning on different mediums or platforms. The chapter starts by presenting the game basics and rules and then - the development and implementation of the ToQ project.

3.1 Game Basics

The GBL system I am using in our experiment is called “Tower of Questions (ToQ)” [49]. The goal is to engage students to create and conquer towers through creating and answering quiz-like questions related to the learning material. The game uses styles, mechanics, and elements found in Tower Defense (TD) games. Tower defence games are a sub-genre of strategic games like board games. There are numerous varieties of this class of games. The most widely recognized examples include building structures (generally as pinnacles, strongholds, and palaces) and applying defensive measures to combat counterattacks by AI or other players [47]. Our ToQ version utilizes game mechanics such as points, quizzes, progress, and elements such as exploration, collection, and community. In the version used in this study, the player earns points in the form of “gems” by creating and attacking other players' towers. A player generates a tower by posting the questions and attacks a tower by solving other users' towers/questions successfully. The students play by logging in with their gamer IDs and passwords [47].

I have created two versions of the game: a web version and a mobile application version. For the web-based version, the front-end implementation uses PHP, HTML, JavaScript, and the back-end – MySQL database [47]. The front-end implementation uses Flutter and Dart, and Google Firebase as a back-end for the mobile-based version. Many parameters need to be set by the instructor to prepare the game for their class. For instance, creating students' accounts with aliases, and defining the maximum number of gems procured from the game during a given time frame, such as a semester. The course instructor determines the number of gems awarded to players for creating

towers and attacking towers. The gems are deducted as a penalty for not playing the game according to the rules. Only partaking students, teachers and researchers can access the game, and the questions and answers asked in the game depend on the course material.

In the ToQ game, students create a new virtual tower every time they pose a quiz question. Every virtual tower expires in seven days if nobody solves the question. Students can choose one of the three types of question towers: multiple-choice question (MCQ), true-false, or short answer. After that, a player selects a domain in which to set up their question tower. The domains correspond to the topics that are covered in the weekly lectures [47]. In our game, every topic/domain is considered a new level of the ToQ game. The creator of a new question tower must provide the correct answer while creating a question so that the attackers' answers can be automatically validated. For the short answer type of question, the creator of the question needs to verify if the answer given by the attacker is correct or not. If the attackers' answer is correct, the reward will be distributed, or the question will be available again for attack. If the question tower is solved or if it remains not solved/conquered, after a certain "expiration date" (7 days), the question and the answer are posted in a list of "conquered" towers where all players can see the answer. Submitting the correct answer helps avoid a disagreement between the creator and the solver player. The students can earn rewards by posing and by correctly answering the questions.

3.2 Rewards Distribution

The game has a finite number of gems or rewards available. These gems are available in a collection called "Bank". At the beginning of the semester, the instructor is responsible for deciding the total number of gems in the bank. A player can earn gems/points by posing a new quiz question. They can earn gems after solving the questions posted by other players. For example, the player is awarded ten gems for creating a new quiz question tower. If any player solves the quiz question successfully, they earn six gems; four gems remain with the player who builds the question tower. The teachers and researchers coordinate and decide the rewards distribution, and it is fixed for the period of our experiment. The distribution of the rewards for our study is as follows:

Table 3.1: The reward distribution of the game.

Action	Gems
Tower creation reward	10
A successful attack on the tower: Reward for attacker	6
Reward remaining for the creator	4
Cost for a player to check conquered and expired towers	4

If a question tower remains undefeated for seven days, all students can see the question with the correct answer, and the player who made the quiz question keeps the ten gems. The points distribution is set to encourage the players to think before posting a quiz question so that the questions are not too easy, which allows them to earn more points [47]. Since the number of gems obtained through the game is limited by the number of gems available in the bank, the players can create new towers (questions) only if the bank contains gems. However, the player can earn points by attacking/solving other players' question towers. Rewards get distributed for true/false and MCQ questions as soon as the player solves the question tower. The points for short answer-type questions are not rewarded until the creator reviews the answer. The creator can reject the answer only three times. This constraint is there to prevent creator from falsely rejecting the attackers' answer. The creator of the SA-type tower question can mark it as correct or reject it.

3.3 Game Rules

Once the student signs into the app version of the system, they see the main page of the game, which contains their total number of gems earned, and a map where they can see their towers after posting a question. The map feature is not included in the web version of the game. Gems are added to the students' gems account when they post a new question, according to the rewards distribution shown in Table 3.1. However, there is a restriction in asking questions to prevent students from gaming the system to gain more than their fair share of rewards. Research shows [48] that the motivation for contributions of the players is negatively affected if there are unjust ways of earning incentives. Gaming the system by creating many repetitive or inconsequential questions needs to be demotivated. Therefore, the total amount of gems to be made in the game is limited, and students can ask a maximum of seven questions at once as long as there are gems available in the bank. If a user posts seven questions at once, they have to wait for the other users to solve them

before posting any more questions. This restriction is in effect to prevent a user from spamming (posting too many questions at once and creating a cognitive overload for the other players).

The game does not have a scoreboard since we do not want players to focus on social comparison [15] but rather on how many gems they can collect. In our game, we want them to practice their knowledge in an enjoyable environment. The players in the game are motivated by achievement; they can earn gems to use other features in our game. Therefore, we used rewards and self-monitoring, commonly used persuasive strategies in behaviour change, to encourage their self-efficacy and motivation to create good questions and answer the questions of their peers. Self-monitoring permits students to focus on and pick what they find beneficial in the game, such as managing their time and practicing their course materials. Hence, there are two pages for the player to monitor their activity. The first one is the map on the main page in the mobile version. The player can see all the question towers they have created on this page. Furthermore, the player can check the questions they solved successfully and attempted to solve in the option "my conquest." The player can observe their progress and action on two pages for the web version. The one is "Towers that I ruled," and the other is a logbook.

3.3.1 Creating Towers

To create a new tower or question as shown in Figure 3.1, the player must choose the 'create tower' option, which takes them to 'select a topic'. Next, they can choose the tower type they want to generate, which includes the options of multiple-choice questions, true/false and short answers. When the player creates a new tower (question), they have to submit the correct answer to the question. After creating a tower in ToQ, it is impossible to change the question. Other players would be allowed to see the question tower once it is created. The expiry duration for the question tower is seven days. If nobody can conquer the tower in that time, the creator keeps the total of 10 gems. After passing the expiration period, the tower becomes available for all players to check the answer.

After a question tower is created, it appears on the "open for attack towers" page in the game and is available for other players to attack. The player who creates the tower cannot attack the tower. The attacker player can solve the posted question only once. If the answer provided by the attacker is not correct, the attacker cannot attempt another answer to avoid multiple guessing. If the answer

of the attacker is correct, the tower will be closed for further attacks, and it moves to the “Conquered towers” (in the web-based version) or “Fallen Towers” (mobile-based version).

We add a constraint of requiring players to spend some gems before opening the fallen towers to view the questions and their correct answers for two reasons. First, the learners have to spend time in the game environment trying to answer questions, hoping to conquer some towers. In the ToQ game, if the player wants to unlock the fallen tower, they must first earn gems. They can do this by creating new towers (questions) and thus contributing to the game, attacking some towers, answering some questions, and practicing their knowledge.

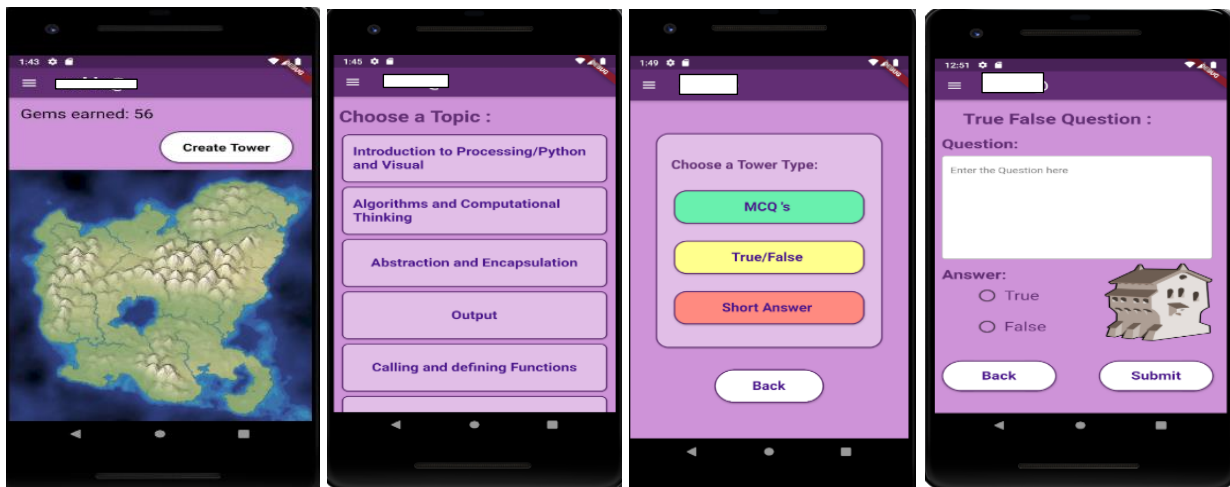


Figure 3.1: Walkthrough of a new question or tower creation process

3.3.2 Attacking Towers

If the player selects the attack tower option, they can see all the existing towers available at the moment. If the player picks a tower and successfully answers the question, the tower is considered conquered: 4 gems out of 10 gems would remain for the creator, and 6 gems move to the attacker, who solves it correctly.

If the attacker answers the question in the short answer (SA) type, the answer goes to the creator for review. After the creator’s decision, the tower is marked as conquered if it is correct, and the gems are distributed between the players. If the creator rejects the given answer, the tower becomes available again for other players to attack or answer. The process of checking a short question is shown in Figure 3.2. Figures 3.3 “Fallen Tower” (mobile version) and Figure F.2 (web version) in Appendix F show where to find the conquered towers.

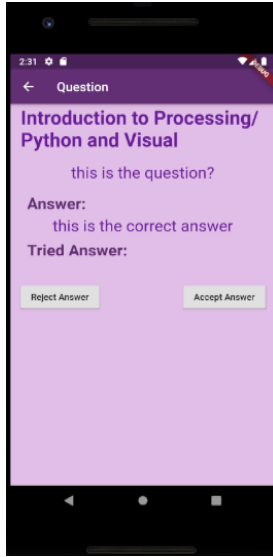


Figure 3.2: Short answers review process

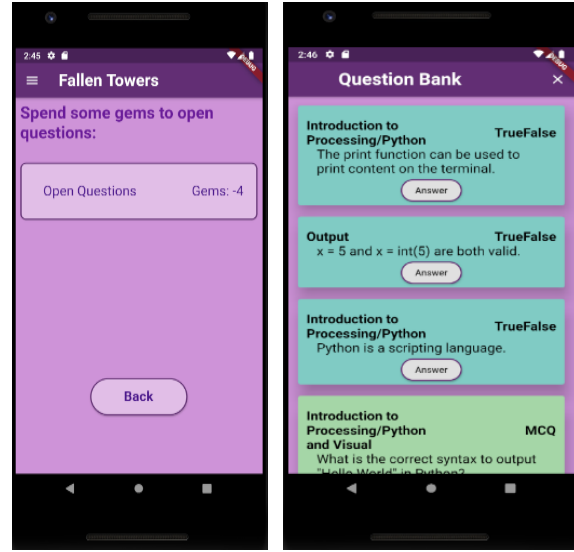


Figure 3.3: Fallen Tower

3.3.3 Conquered Towers

The question tower becomes available for everyone to view along with its answer when it is attacked successfully or when it expires. These towers appear in the Fallen Towers (Figure 3.3) or the Logbook option in the web version, as shown in Figure F.2 in Appendix F.

The fallen or conquered towers comprise the question-and-answer bank [47]. In the web version, these towers become open to all the players to browse; whereas in the app version, the player can access these towers when they have at least four gems in their account. After using these gems, the player can access all the questions in the question bank. If the player does not have any gems in their account, they will not be able to access the questions bank.

3.4 Development and Implementation

This section highlights the framework that includes the designing and implementation of the Tower of Questions game mobile application. The original web version of this game was developed by Nafisul Kiron and was evaluated during two studies over two consecutive years in a first-year programming class at the University of Saskatchewan. Details on the web-based version of the game and its evaluation can be found in [47]. I developed the ToQ mobile app, deployed it, along

with the web-version, in a first-year programming class at the University of Saskatchewan, and carried out a study to compare the student engagement in the two versions of the game.

The technology used in the mobile app implementation of the ToQ is described below:

- i. *Visual Studio Code (VS)*: Developed by Microsoft, the VS editor is ranked the most popular code editor and is widely used by developers. The VS editor supports many languages such as CSS, HTML, Ruby, Java, Python, JavaScript etc. It features integrated Git software for tracking code changes. Visual Studio connects seamlessly with other innovation tools like Docker, Kubernetes, and GitHub. To develop the ToQ application, I used VS code version 1.47. I chose to use VS Code as the code editor because it is easily extensible and lightweight. There are numerous assets and documentation accessible which makes it simple to set up (Figure 3.4).

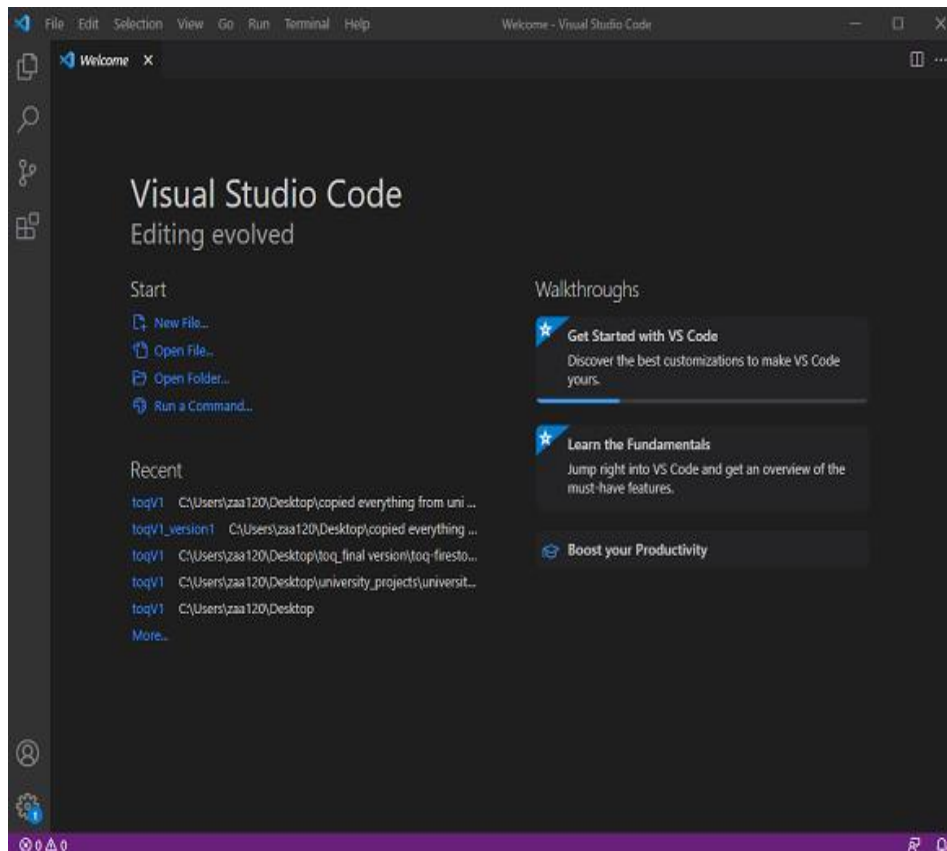


Figure 3.4: A screenshot showing the ToQ VS setup

ii. *GitLab*: GitLab is the Git repository management system. Its web interface is user-friendly. Creating project documentation or following required changes with the issue tracker are built-in features in GitLab. Projects are established in repositories, and they can easily be shared for collaboration and contribution with other developers. A screenshot of the ToQ repository is shown in Figure 3.5. GitLab enables developers to generate a private repository and contains robust documentation, which makes it an excellent option for an environment to develop the ToQ game.

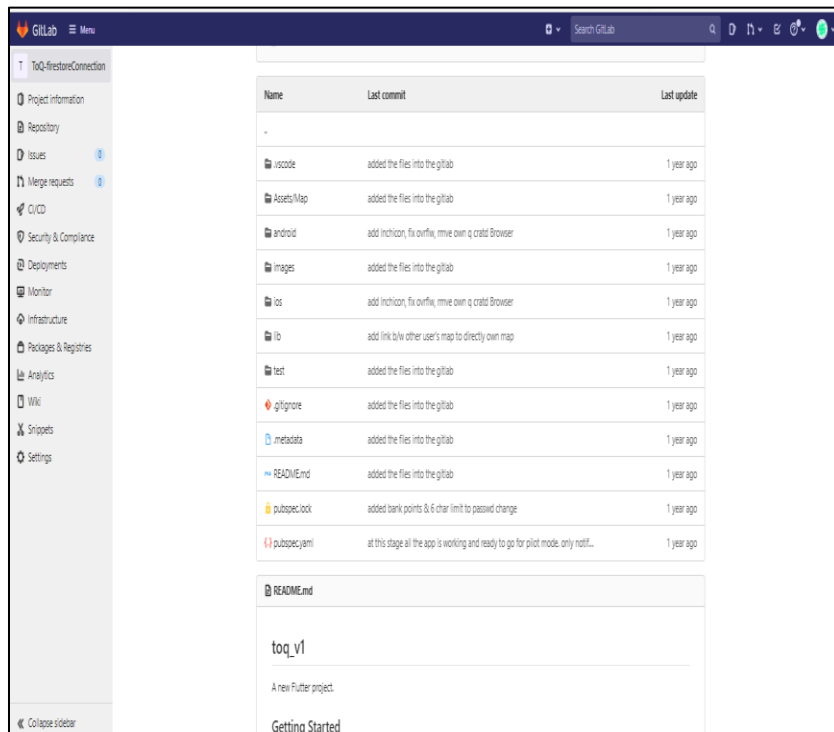


Figure 3.5: Showing Gitlab repository for ToQ

iii. *Google Firebase*: Google Firebase is a Google-backed application advancement software that empowers developers to develop Android, Web, and iOS applications. It enables programmers to concentrate on optimizing the user experience. Firebase is a server, data storage and API, all composed conventionally, so it tends to be altered to suit most necessities. That is the reason it is an ideal choice for the ToQ game. Figure 3.6 shows the Google Firebase console.

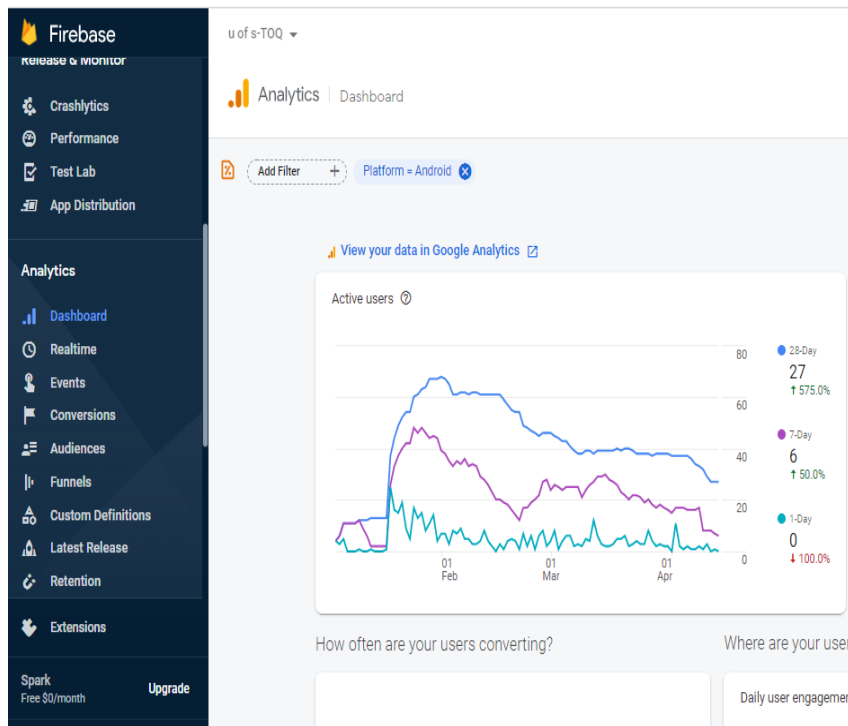


Figure 3.6: Showing Google firebase console for ToQ

Google Firebase offers many services, including analytics, authentication, cloud messaging, real-time database, crashlytics, performance and a test lab. Some of these services which are used in the development of the ToQ game are Cloud storage, authentication, Cloud functions and a Cloud Firestore database. The Firebase services we use in the development of ToQ are discussed below:

- a. *Authentication*: Most applications need to know the identity of a user. Recognizing a user's identity permits an application to safely store user information in the cloud and give a similar customized experience at whatever point they sign in. Firebase Authentication provides backend administrations and instant UI libraries to confirm users to your application. Firebase has email and password-based authentication, which helps to manage the ToQ user. The ToQ user only uses the credentials that an authorized person sends them by email. ToQ also uses the firebase authentication feature of sending password reset emails [50].

- b. *Cloud Firebase Database*: A NoSQL database is designed to store and synchronize user data in real time. It also provides offline access by saving a database cache on the user's device and uploading it when the user connects to the internet [50]. This offline data storage is an appropriate choice for the ToQ application, as the users may be out of connectivity from time to time, for example, while travelling.
 - c. *Cloud functions*: Firebase Cloud Functions is a serverless platform that enables running backend code on firebase features and prevents developers from processing and managing their servers. The firebase cloud function is triggered by events transmitted by google administrations or outside (outsider) administrations [50].
-
- iv. *Flutter*: Flutter is an open-source (UI) software development kit (SDK) made by Google utilizing the Dart programming language. Flutter uses Cross-platform SDK for the development of the application. It can develop applications for various platforms, including iOS, Android, Mac, Windows, Linux, and the web using a single codebase. Because Flutter SDK has a rich widget library that results in a beautiful UI, I used it to develop the ToQ application version [51].
 - v. *Android Studio*: Android Studio is an official environment and provides the fastest tools for building apps on any Android device. It is based on IntelliJ IDEA software and is accessible for Linux, Windows, and Mac. I use the Android studio emulator while developing the ToQ app because it has a built-in emulator, allowing me to test-run the applications without connecting to an external device [52].
 - vi. *Google Play Store*: It is an approved application store for certified devices operating on the Android system, permitting clients to peruse and download applications created with the Android (SDK) and distributed through Google [53]. ToQ is released in the Google play store shown in Figure 3.7.

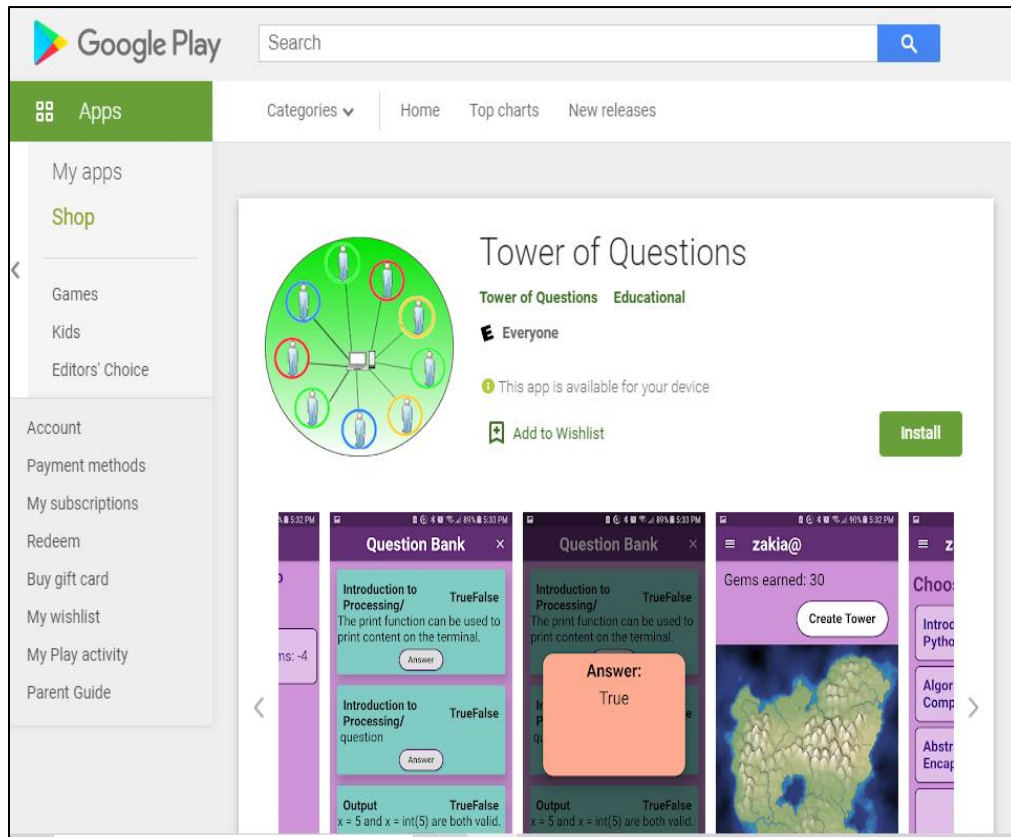


Figure 3.7: ToQ in the Google app store

vii. *Android Operating system:* Android is a mobile operating system created by the Open Handset Alliance and industrially supported by Google. The operating system was launched in 2008 and planned fundamentally for touchscreen mobile devices, for example, cell phones and tablets. As of September 2021, the Android OS is the most extensively deployed mobile OS, representing 72.73% of the market [55]. The Android OS has had many redesigns that have been steadily run on its working framework by adding new provisions and fixing mistakes in past renditions. The ToQ app can be downloaded only on a device using the Android operating system.

This chapter presents the game design, reward distribution, development, and implementation of the ToQ game. The next chapter presents the experimental design of the study, the participants of

the study and the method in which the mobile and web-based versions of ToQ were deployed and compared. It also explains about the pre and post survey questionnaire.

CHAPTER 4: RESEARCH DESIGN

The mobile application version of the ToQ game was created to enable learning by playing the game casually in different contexts, such as students moving on campus or travelling on the bus. The game-based learning supported by ToQ allows the students to practice the learning material and prepare better for quizzes and class exams. However, during the Covid-19 pandemic, classes moved online, and students studied from home. Naturally, a research question arises: would students use the application version of the ToQ on their smartphones or prefer to use the web version on their laptops when they are not in motion?

So, this research focuses on comparing a mobile application-based version and a web-based desktop version of an educational game to see which is more effective in engaging students. We experimented in a first-year programming class at the University of Saskatchewan to answer the research question. Participation in the study was voluntary for the students. The experiment was approved by the University's Behavioral Research Ethics Board with Certificate BEH 101 (see Appendix D).

The next section presents the experimental design.

4.1 Experimental Design

We experimented with ToQ at the University of Saskatchewan for an entire academic semester (from January to April 2021). The experimental design was semi-random with non-equivalent groups. The participants were divided into two groups: control and test. We evaluated in parallel the two versions of the ToQ game. The first was the web version of the game, which had already been tested in the previous experiment [49] and was used by the control group in the current experiment. The application version of the ToQ game was used by the participants in the test group. We did not use a fully randomized experimental design because of the platform restriction (the app runs only on the Android OS), which made it impossible to assign the subjects to two groups randomly. Therefore, we used a semi-random assignment of the participants to one of the two groups. Only students with Android smartphones or tablets were assigned to the test group, while

the control group using the web-based version of ToQ contained students some of whom also had iOS and Android smartphones.

Both versions of the game have the same functionalities: posting a new question, answering the questions posted by other users, and choosing the question type. There is a slight difference in the aesthetic of both versions. For instance, the application version has different colours for different pages, whereas the web version has simple visuals. In the app version, the user can see all their created towers/ questions on the map while this option is not available in the web version.

4.2 Participants

The participants were first-year students taking an Introduction to Computer Science course (CMPT 141). We recruited the students through the course management system that was used in the class. Students could get bonus participation marks of up to five percent of the grades in the course if they participated actively in the ToQ game. The students had to post at least three towers/ questions per week to receive bonus marks. The participants got their weekly progress reports by email to track their contributions. The students who gave informed consent to participate were included in this study and qualified to receive up to 5% bonus marks in the class if they played the game regularly and actively. The students who did not participate in the study had the 5% bonus marks moved towards the final exam. The participants had the option to withdraw from the study anytime.

A pre-study survey was used to divide participants into groups. The questions asked in the Pre-survey were as follows:

- i. *What type of phone do you use primarily:* This question had two options to choose from "Android" and "Apple." If the participant selected the Android option, they were provided with a link to download the application version. The participants who chose the Apple option were directed to the link to the web version of the ToQ.
- ii. *Please enter your NSID:* NSID is the unique network system ID assigned to all University of Saskatchewan students which provides them with a university email address. Students who participated in the application version were sent an email, at their NSID email address, providing them with their username and password along with a link to download the ToQ application. The participants who signed up for the

web-based version of ToQ got the URL link for the ToQ game, along with their username and password. The participants needed their username and password to play the game (Figure 4.1). The username anonymized students to each other while playing the game, so their privacy was preserved. The authorization step assured that only approved participants could join the study and prevented people outside the class who downloaded the application on the Android marketplace from interfering with the experiment. Participants that came to this stage had met all the prerequisites to partake in the study.

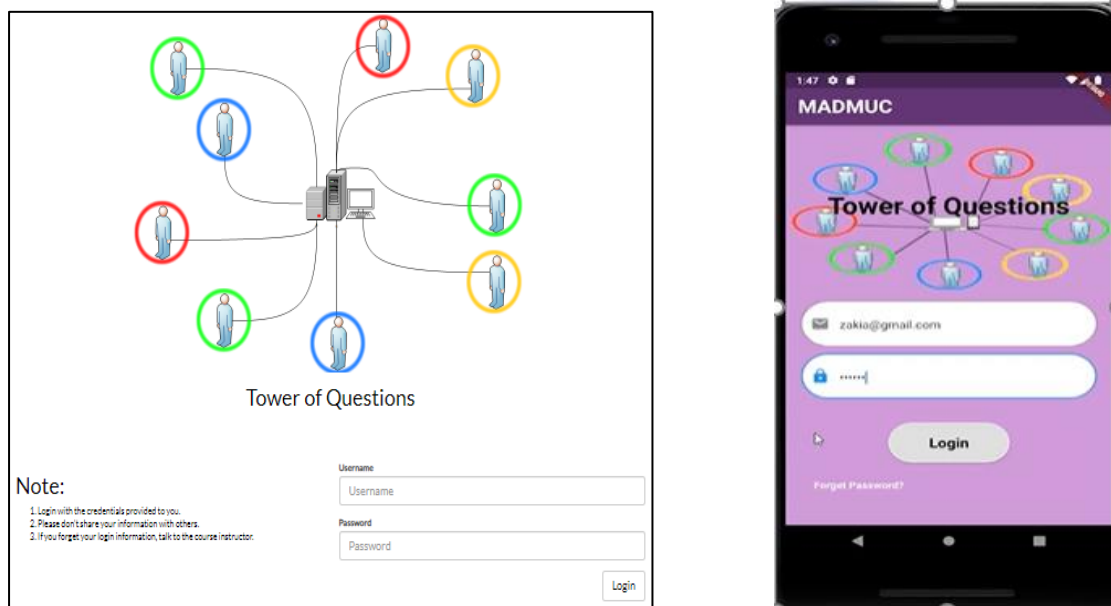


Figure 4.1: Login page for web version and mobile version

The information recorded from the game includes the number of active users in the game each week and the total number of towers created each week by the active users, and the number of towers successfully attacked by the active users each week. For my all results, I considered active users those who logged in and created at least one tower in a week in the system. Initially, all participants had zero reward points in their accounts.

4.3 Pre and Post Questionnaires

I conducted the pre- and post-study survey using SurveyMonkey. SurveyMonkey is a cloud-based survey tool to help conduct surveys. The pre-study questionnaire gathered the participants' demographics and experience in playing computer games and their authorization information. The Post-study questionnaire asked about the participants' perception of the usefulness of the game and their experience with the game. The complete pre-study survey is shown in APPENDIX A, and the Post-study survey is shown in APPENDIX B.

Firstly, the Shapiro-Wilk test in SPSS was performed to test the data normality, and the result showed that the data were not normally distributed. So, I used the non-parametric Independent Samples Mann-Whitney U Test in SPSS for the data. I compared the difference between the means of two groups (experimental and control group) when the variable is not normally distributed. Secondly, I converted the data into normal distribution and performed the independent sample T-test. I compared the differences between the means of two independent groups.

I investigated the number of towers created every week on the web and the application version of the game. Also, I examined the active users every week in both versions of the game. I also analyzed the rating for both versions of the game by the user. The results are presented in the next chapter.

CHAPTER 5: RESULTS AND DATA ANALYSIS

This chapter explains the results of the data analysis performed to determine whether the mobile-based or web-based version is more effective in engaging students in the ToQ game-based learning environment during the pandemic.

One hundred twenty-one participants completed the Pre-study questionnaire (see Appendix B). Of the participants, 71 (58.6%) participants used the web version (group W), and 46 (38%) participants used the 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, so any participant who had only iPhones or other non-Android devices had to use the web version of the game.

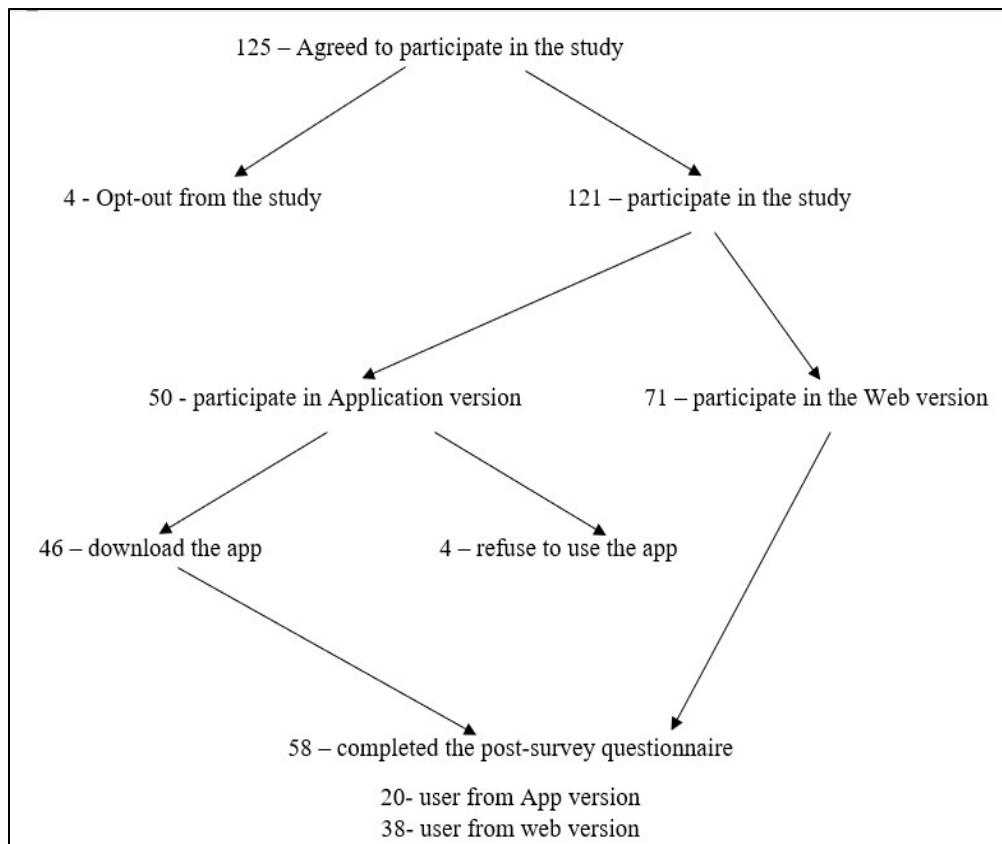


Figure 5: Participant summary

The study lasted for an entire academic semester (four months), from January to April 2021. At the end of the semester, the participants completed the post-study questionnaire.

5.1 Quantitative Results

This section presents the results by investigating the engagement metrics each week in both versions of the game and the game rating. The 71 participants in the control group (we will call it for simplicity from now on W for the “Web version” group) collectively created 1328 towers throughout the semester. The 46 participants in the test group or A (Application) group downloaded the application and built 961 towers (see Table 5.0).

Table 5.0: Participation summary of both groups.

Game version	Participants	Total towers created
Web (W group)	71	1328
Application (A group)	46	961

The independent variable in our study is the version of the game used by each of the experimental groups. The dependent variables are the following engagement metrics: the active users per week, the number of towers created by the active users each week, and the number of towers successfully attacked by the active users each week. For all results, I 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.

All the dependent variables are explained below:

1. Active users: For comparing the number of active users in both groups, I formulated the following null and alternative hypotheses:

H_0 : There is no difference between the number of active users in the A and W groups.

H_1 : There is a difference between the number of active users in the A and W groups.

Figure 5.1 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 of the game, the graph shows that active users were 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. I performed the Shapiro-Wilk test in SPSS and the data were not normally distributed. To compare data from two independent groups with non-normal distribution, I performed a non-parametric Mann-Whitney U Test in SPSS.

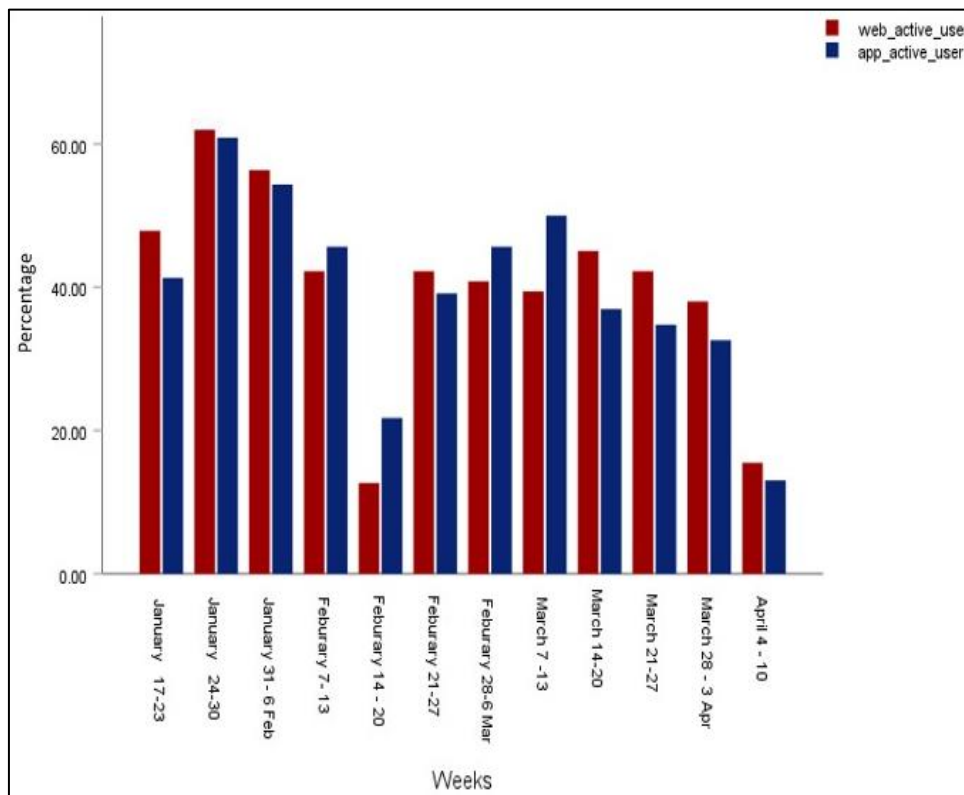


Figure 5.1: The percentage of active users per week in each version.

The test summary for Independent Samples Mann-Whitney U Test for active users in both groups is shown in Table 5.1.

Table 5.1: Mann-Whitney U test for the number of active users

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The number of Active_user is the same across categories of groups.	Independent-Samples Mann-Whitney U Test	.755 ^c	Retain the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.
c. Exact significance is displayed for this test.

Table 5.1.1: Group Statistics for the number of active users

Report			
Active_user			
groups	Mean	Std. Deviation	Median
App	39.6739	13.34065	40.2174
Web	40.3756	14.15263	42.2535
Total	40.0247	13.45512	41.7789

Table 5.1.2: Test Summary for the number of active users

Test Summary	
Total N	24
Mann-Whitney U	78.000
Wilcoxon W	156.000
Test Statistic	78.000
Standard Error	17.302
Standardized Test Statistic	.347
Asymptotic Sig.(2-sided test)	.729
Exact Sig.(2-sided test)	.755

2. Towers Created: For the engagement metric “number of towers created per active user of the game in each week”, the null and alternative hypotheses are:

H_0 : There is no difference between the average number of towers created by the active user in groups A and W of the game.

H_1 : There is a difference between the average number of towers created by the active user in the A and W groups of the game.

I performed a non-parametric Independent Samples Mann-Whitney U Test in SPSS on the data. The graph illustrates the mean number of question towers posted by the active users each week (towers created) in the application version is greater as compared to the web version of the game.

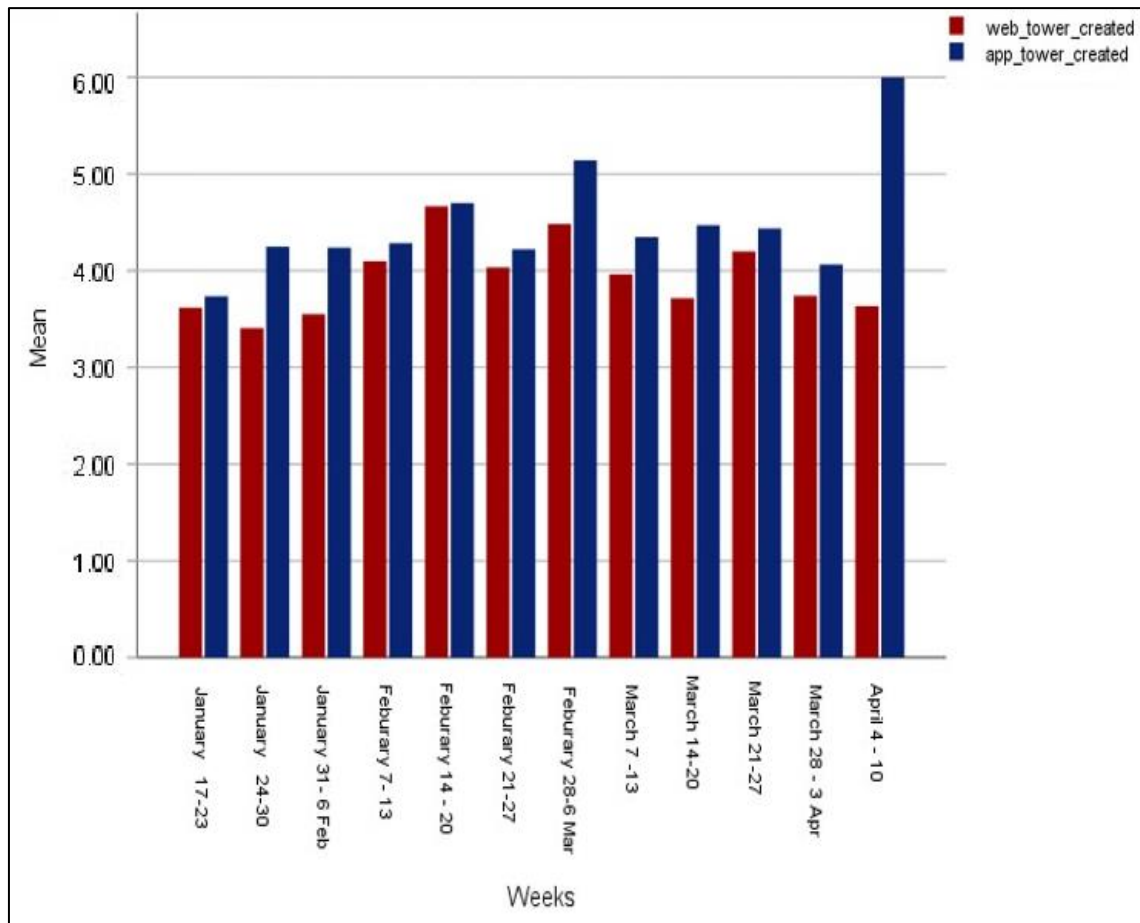


Figure 5.2: The mean number of towers created by active users in each version per week.

The Independent Samples Mann-Whitney U Test results for towers created by active users are shown in Table 5.2. The result shows that the number of towers created by the students in the test group using the mobile app version is significantly higher than that of the control group.

Table 5.2: Mann-Whitney U test for tower created by the active user

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of Tower_created is the same across categories of groups.	Independent-Samples Mann-Whitney U Test	.006 ^c	Reject the null hypothesis.
a. The significance level is .050. b. Asymptotic significance is displayed. c. Exact significance is displayed for this test.				

Table 5.2.1: Group Statistics for the towers created by the active users

Report			
Tower_created			
groups	Mean	Std. Deviation	Median
App	449.1685	58.41645	431.6770
Web	392.6636	38.63249	385.2513
Total	420.9161	56.38040	421.1111

Table 5.2.2: Test Summary for the towers created by the active users

Test Summary	
Total N	24
Mann-Whitney U	25.000
Wilcoxon W	103.000
Test Statistic	25.000
Standard Error	17.321
Standardized Test Statistic	-2.714
Asymptotic Sig.(2-sided test)	.007
Exact Sig.(2-sided test)	.006

3. Towers Solved: The null and alternative hypothesis for number of towers solved by the active users per week is as follows:

H_0 : There is no difference between the average number of towers solved by the active users in groups A and W.

H_1 : There is a difference between the average number of towers solved by the active users in the A and W groups.

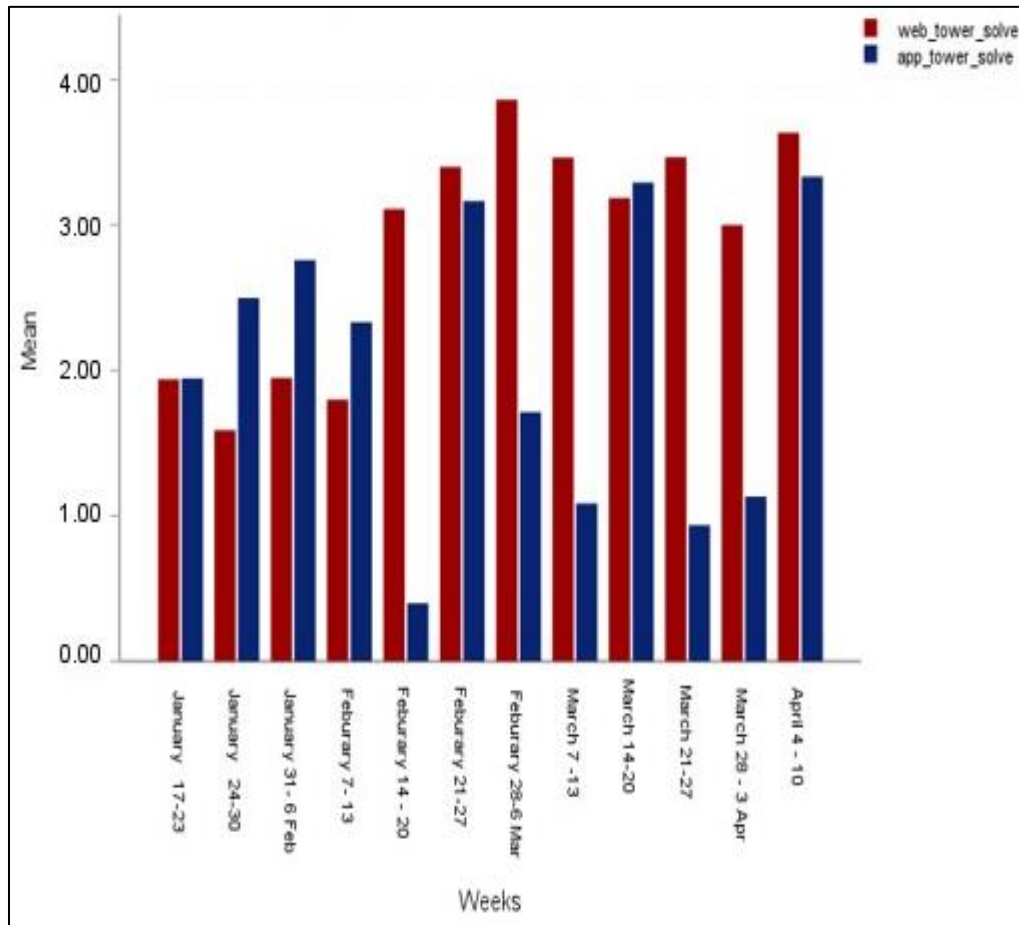


Figure 5.3: Mean number of towers solved by the active users in each version per week.

Figure 5.3 shows the mean number of towers attacked by the active users per week. These results only include the 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 reading week (Feb 7-13), the participants in group W were more active in solving questions towers and only in two weeks did the participation of group A come close to that of group W.

The results from the Independent Samples Mann-Whitney U Test for towers solved by the active users are shown in Table 5.3.

Table 5.3: Mann-Whitney U test for tower solved by the active user

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of Tower_solved is the same across categories of groups.	Independent-Samples Mann-Whitney U Test	.039 ^c	Reject the null hypothesis.
a. The significance level is .050. b. Asymptotic significance is displayed. c. Exact significance is displayed for this test.				

Table 5.3.1 Group Statistics for tower solved

Report			
Tower_solved			
groups	Mean	Std. Deviation	Median
App	205.0575	100.36169	214.0351
Web	286.7507	81.05808	314.9306
Total	245.9041	98.49175	263.0000

Table 5.3.1 shows that the mean and median number of towers solved by active users in group W is higher compared to group A. 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 easier to read the question and compare the options in the web version. Whereas, in the app version, the students have to remember all options to compare them, and it could result in a cognitive overload for the student.

Table 5.3.2: Test Summary for tower solved

Test Summary	
Total N	24
Mann-Whitney U	108.000
Wilcoxon W	186.000
Test Statistic	108.000
Standard Error	17.321
Standardized Test Statistic	2.078
Asymptotic Sig.(2-sided test)	.038
Exact Sig.(2-sided test)	.039

In the app version, users could check the old solved and expired questions by spending four gems from their rewards bank. The data shows that 69.56 % of the participants opened the question bank during the term; the participants opened the question bank 90 times throughout the term. The analysis shows that the participants posted more True False towers when compared to the other question types in both versions of the ToQ game. Figures 5.5 and 5.6 show the summary of the question type created during the research period.

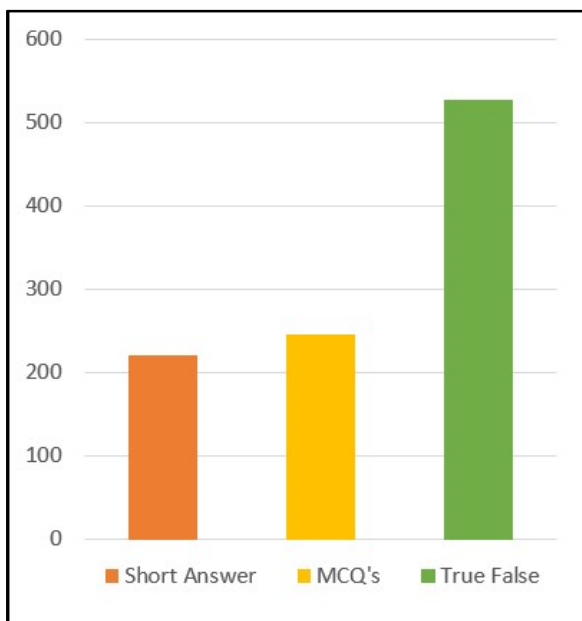


Figure 5.4: Tower type created during the research period in Application version

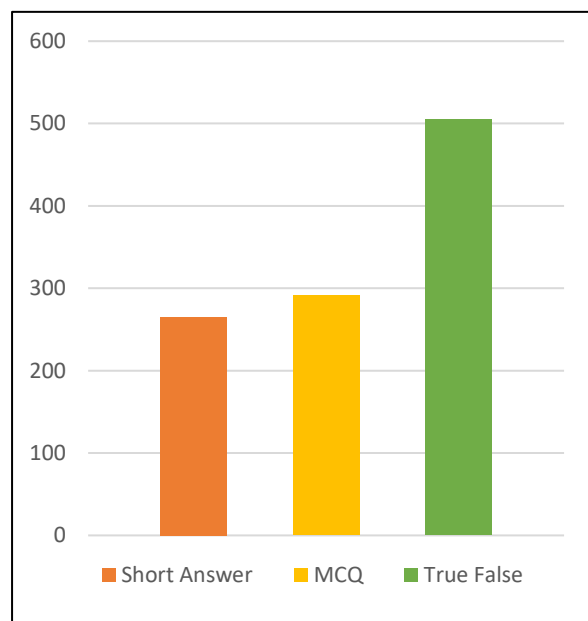


Figure 5.5: Tower type created during the research period in Web version

5.2 User Experience

In the post-survey questionnaire, we asked the participants to rate their game experience on a scale of one to five, with one being the least satisfaction rating on the Likert scale and five being the highest satisfaction with the system. 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 as shown in Figure 5.3. The majority 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 have almost the same rating from the participants.

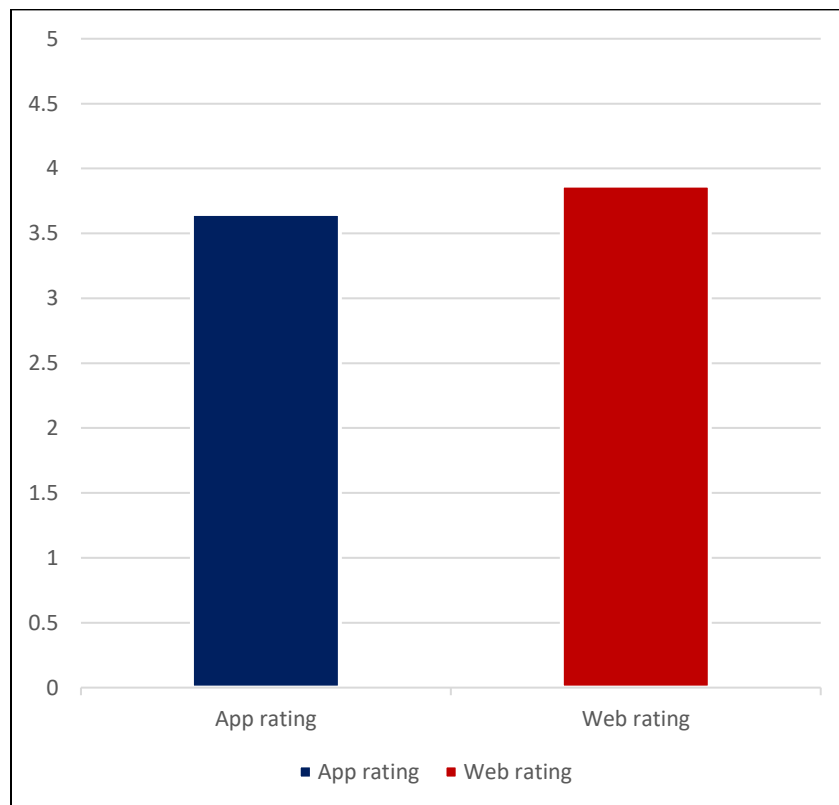


Figure 5.6: User rating for both versions

The final questionnaire result analysis shows that the participants like to create questions in both versions of the game. The questionnaire contained the question "Which feature(s) did you like the most (in the game)?". The result of that questionnaire shows that 55.26% participants in the web and 65% participants in-app version preferred posting the questions, and 26.31% participants on

the web and 15% participants in an app liked solving the questions in the system. Furthermore, the results show that 18.42% participants on web and 20% participants on an app version like the other features of the game which include collecting points, reading from the question bank, and flagging the question.

5.3 Detailed Statistical Analysis Report

I have compared the results of two versions of the game-based learning tools for 12 weeks. I have presented the results using two methods in SPSS: the Mann-Whitney U test (the results are reported in Section 5.1) with statistical significance level $p = 0.05$, and the Independent Sample T-test (see Appendix G for the results).

5.3.1 Active Users

The total number of users who actively participated in our study was 117. Of the total number of participants, 60.68% (71) signed up for group W (Web) and 40.38% of these 71 participants from group W actively participated in the study. The remaining 46 students were recruited for group A (App), out of which 39.67% were the participants who actively participated. The statistics show a very slight difference 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 number active user in both groups. Results analysis indicates no significant difference between the number active users in both groups. In Table 5.1.1, the mean of active users for group W ($M = 40.3$) is higher than the mean of active users in group A ($M = 39.6$), but the Mann Whitney test indicated that this difference is not statistically significant, $U = 78$, $z = .347$, $p > 0.05$ ($p = 0.75$). These results demonstrate no difference between both groups, so we retain the null hypothesis (H_0) (Table 5.1). The mean difference of active users is by chance because the significance value p is greater than 0.05. We cannot generalize this result to the population. In short, there is no difference between the active users of groups A and W.

To further support my hypothesis, I also performed a T-test. Since the data were not normally distributed, so I used the square root method to convert the data. After normalizing, I performed the Independent Sample T-test. Firstly, Group A has active users mean for 12 weeks $M = 4.20$ ($SD = .78$). By comparison, group W has a smaller mean of active users for 12 weeks $M = 3.83$ (SD

= 1.34). To test the hypothesis that Group A and W have a statistically significantly different mean of active users, an independent sample T-test was performed. 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, $t(22) = 0.832, p = 0.414$. Thus, there is no difference between the mean of active users in Group A and W. Cohen's D was estimated at 0.340, which is a small effect size based on Cohen's (1992) guidelines [57].

5.3.2 Towers Created

From the results presented in this study, I have been able to show that more towers on average were created by an active user in the application version of the game. I conducted a Mann-Whitney U test to check the difference between the tower created in groups A and W of the game. Test analysis shows a significant difference between the tower created by active users in groups A and W. The median of tower 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, $U = 25, z = -2.714, p < 0.05$ ($p = 0.006$). These results state a substantial difference between the towers created in both groups. Also, as shown in Table 5.2.2, 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 an in-app 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. Table 5.2.1 shows that the mean and median for tower created by active users is higher in group A as compared to group W. The report (Table 5.2.1) shows that participants prefer to use the application version while posting a new question.

Moreover, an independent sample T-test was performed to test the hypothesis that Group A and W have statistically significantly different mean numbers of towers created by active users. For 12 weeks, Group A has mean towers created by active users $M = 8.83$ ($SD = 1.47$). By comparison, group W has a statistically smaller number of mean towers created by active users $M = 5.80$ ($SD = 2.68$). 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 very large effect size based on Cohen's (1992) guidelines.

This quantitative result is confirmed by the qualitative data. In the post-study questionnaire, we asked participants, "which feature(s) did you like in the game?". The data shows that 17 out of 20 participants preferred creating a question in the application version of the game.

5.3.3 Towers solved

I investigated the results for solving towers by active users in both groups for each week. The graph shown in Figure 5.2 shows the mean of successfully solved question towers by the active users. I have not included the data when users tried to solve the question but were unsuccessful. The statistics show that, on average, the participants in group W solved 34.48% more question towers than group A throughout the term. A Mann-Whitney U test is conducted to determine whether there is a difference between the average number of towers solved by active users every week in the A and W groups of the game. Results of that analysis indicated that there is a significant difference between the tower solved by active users of both groups. The average number of towers solved by the active users in group W (MD = 314) is higher than the average number of towers solved by the active users in group A (MD = 214). The Mann-Whitney test indicated that this difference is statistically significant, $U = 108, z = 2.078, p < 0.05$ ($p = 0.039$). The results show a considerable difference between the tower solved by active users in both groups. Furthermore, we accept the alternative hypothesis and reject the null hypothesis because the two-tail significant value is less than 0.05 (Table 5.3.2). The statistical report shows that the mean number of towers solved is higher in the web version ($M = 286.7$) as compared to the app version ($M = 205.05$).

Lastly, the average number of towers solved by active users in group A is $M = 5.85$ ($SD = 1.99$). By comparison, group W has a higher average number of towers solved by active users $M = 8.67$ ($SD = 1.66$). To test the hypothesis that Group A and W have statistically significantly different means for the number of towers solved by active users, an independent sample T-test was performed. 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 very large effect size based on Cohen's (1992) guidelines.

5.4 User Feedback

This section presents the review and brief analysis of the post-survey questionnaire that the users filled out at the end of the survey, with comments and feedback. The students gave a positive response to the system in their feedback. We got an overall satisfaction result toward the learning system. Some of the comments are given below.

- *“I thought it was a fun experience to have as part of my computer science course. Collecting points by solving problems associated with course content was rewarding, and improved my knowledge of these concepts.”*
- *“the game is well thought of”*
- *“well done and fun game”*
- *“Overall, it was an amazing game :)”*
- *“the game was a good switch from more traditional learning methods.”*
- *“It was a good learning game”*
- *“An amazing experience”*
- *“This idea was really a fun way of learning and revising things with our peer-mates.”*
- *“I think it was pretty good overall”*
- *“It was an interesting experience for me and I learnt a lot of things without any stress and pressure. Learning without stress.”*
- *“I enjoyed the game and it helped me to get the readings done every week. Overall very good!”*
- *“I thought it was a super fun and unique way to learn!”*

- *“I really liked this experience!”*
- *“No, but the game was a good switch from more traditional learning methods.”*

There were also some negative comments or suggestions from the students.

- *“the map, It would be nice to see everyone's towers and if you could click on said tower to attack it.”*
- *“there is limited formatting ability in making the questions.”*
- *“I think email reminders are a little annoying! Because sometimes you get a bunch of emails at the same time, which makes people feel upset, especially during the rest day. So, I think using group chat is definitely better than email reply! In this way, people who are not interested will not see these messages. And people who are interested in some questions can discuss freely rather than discuss openly.”*
- *“The mobile app hardly worked as designed for me, so app design and bug fixes would be nice.”*
- *“Formatting of questions. Sometimes there seemed to be issues with the multiple choice questions.”*
- *“The APP UI could use some work, as it was sometimes difficult to move between sections”*
- *“I believe there might be some glitches cause when answering a question correctly, does not get the point. Or tell what mistake they made when answering the question.”*
- *“There should not be Tower Limit”*
- *“the login system could use a remember me option, its annoying signing in everytime when i use the app”*

These comments from students were quite noteworthy. They show that game-based learning helps them practice their course material in a fun way and allow them the opportunities to revise it with their classmate. From the total number of participants who completed the post-survey questionnaire, 38% gave positive feedback and 5.1% of the participants gave negative feedback about the system. Forty-three percent 43% of the participants provided the neutral responses, and 13.8% of the participants gave suggestions for improving the system. Hence, most of the comments

in the post-survey indicate that students liked the system, and it could motivate students to modify their learning habits and encourages more active participation. These suggestions could be helpful in a future study.

CHAPTER 6: CONCLUSION AND DISCUSSION

This thesis investigated the effectiveness of an application-based version and a web-based version of an educational game in engaging students by evaluating them in parallel and comparing the results from both versions. To this end, I compared the engagement of students using two versions of the Tower of Question game. One was the web version of the ToQ game, and it was used with the control group of the participants. I used the web version with the control group because it was already tested in the previous years. I developed a second version of the game as a mobile application, and it was used with the participants of the experimental group. Both versions have the same functionalities, such as posting a new question, earning points, solving the questions posted by other users in the system etc. The main differences between the versions were related to the aesthetics: the application version had a more vibrant colour than the web version, the interface design, and the implementation platform

The only difference in the game rules between the two versions was the new rule in the app version requiring players to pay some of the gems they have earned in order to see the solved questions. This game rule was a last-minute addition to the mobile version inspired by the idea of adding some value and purpose to accumulating gems in the game, increasing the players motivation for creating and attacking towers, since both of these actions earn gems. The older (web) version did not have this rule and the players had no real use for the collected gems; they could check the solved questions at any time without any “cost”. The result of the experiment showed that the students in the app version and spend some of their gems to view the solved questions.

I employed a quantitative approach to collect data to determine which version is more effective in engaging students in game-based learning. I used three measures for engagement for each group: number of active users per week, number of new question towers created, and number of towers solved. The result of the data analysis provided the answer to the research question “which version is more effective in engaging students in the game-based learning the web or the application version?”.

The evaluation of the game-based tools shows that overall, there is no statistically significant difference between the engagement of students using the two-version measured by the number of active users per week. However, there is a significant difference in the kind of activities they engage in. The group using the mobile app version engaged more in creating new questions, while the web-based version group engaged more in solving questions, especially during the second half of the term. One reason for creating more towers in app version could be because of the tunnelling persuasive design strategy used for the interface for creating towers as shown in Figure 3.1. It was not possible to apply the same design for answering questions because it could create confusion in giving the answer. Another explanation of the result that the students in the mobile version created more questions than the students in the web version could be the new game rule requiring “payment” of gems to access the solved questions, since students in the app version may have had a higher motivation to collect gems and may have found it easier to earn gems by creating questions rather than answering them.

The result shows that both platforms can engage students and increase learning through practicing question asking and answering. Both versions of game-based learning are helpful by providing value to the user and helping them achieve their goal of practicing their course material. Other research also supports these findings such as business/ marketing [56, 38], education/learning [24, 17, 28], health/work out [33, 34, 35, 30].

Research shows that game-based learning is used to achieve specific goals in the educational domain. Game-based learning has been utilized in various settings, including teaching complicated concepts, inspiring people to pursue higher education, educating persons with learning problems, and self-regulated training. Hence, understanding the impact of game-based concepts and methods on students' participation in their learning activities would help in the development of relevant game-based applications for the education field. This research has investigated the participants' engagement with different game-based learning platforms. We need further experiments to determine whether the differences between the web and app versions will continue to manifest themselves. One recommendation resulting from this 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.

6.1 Limitations

There are several limitations in this research. Firstly, the study setting is limited to a single university course designed to enhance students' involvement in learning activities. The game-based learning applied to only one computer science course the students took in their first semester. Second, the study compares two versions of the application. The app version was created to allow students to use it on the phone and is available anywhere. Because of the pandemic lockdown, students studied from home and used their laptops or desktop systems instead of using mobile phones because of the larger screen size, keyboard, and general convenience. Third, because the intervention was only implemented for one academic term, the findings in this thesis may not explain the intervention's long-term impact on students' involvement. It is not possible to say if students' perceptions of game-based methods will alter over time if they use the system longer. Finally, students' involvement was judged solely through their online activities; textbook learning and scheduled study sessions were not included. The study did not compare the participants' grades with their game involvement.

6.2 Future work

This section presents some relevant issues that were not explored in this thesis. I would like to study them in future studies.

1. Investigating the effect on users in post-pandemic

The study period presented in this thesis was during the pandemic when students were studying from home and had minimum mobility. I would like to analyze the effect of both versions in a situation where students would have the advantage of mobile access while moving such as they are on a bus, walking, or playing a game in their leisure time etc.

2. Investigating the effect of the game with availability on both operating system

It would be very interesting to investigate the effect of the game when available on both operating systems such as Android and iOS. So, we can perform the same experiment but randomly assign participants to use any version of the game, the web-based or the mobile-based.

3. Long-term effect of different GBL platforms

This study was only conducted for a period of four months. The results of this research might not reflect the long-term effect of GBL platforms on users. In future research, we can explore the long-term effect of the different GBL platforms by conducting studies for more than a year.

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APPENDIX A

TOWER OF QUESTIONS: PRE-STUDY SURVEY

1. Please enter your NSID

2. Gender

Male

Female

Other

3. Do you play video games in any platforms (PC, Mobile, Console etc.)?

Yes

No

4. How many hours do you spend playing games each week?

5. Are you familiar with Tower Defense Games?

Yes

No

6. If you answered YES in the previous question, name some Tower Defense games you have played.

Game 1

Game 2

Game 3

Game 4

7. Do you submit your assignments in time?

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

8. How many late assignment submissions do you have in the last 6 months?

None

<3

3-5

5-7

>7

9. Do you like to work alone or in a group?

Alone

Group

10. What's your ideal group size?

11. What is your most preferred time for studying?

8am-12pm

12pm-4pm

4pm-8pm

8pm-12am

12am-8am

12. How many hours do you study each week?

APPENDIX B

TOWER OF QUESTIONS: POST-STUDY SURVEY

1. What is your NSID?

2. Do you think it was useful as a learning tool?

Yes

No

3. Did you find it fun to learn the material in this way?

Yes

No

4. How did you find the questions your class-mates asked?

Not challenging

Too easy

Good

Too challenging

5. Which part of the game did you enjoy most?

Creating towers

Attacking towers

Viewing conquered towers

Reporting towers

6. Which part of the game did you find most difficult?

Creating towers

Attacking towers

Viewing conquered towers

Reporting towers

7. If you are given a chance to try the system again, do you think you can do better?

Yes

No

8. Do you want to try the system in other courses?

Yes

No

9. If you answered YES in last question, which course do you want to try the system on?

10. Which feature did you like the most?

11. Which feature do you think needs improvement?

12. Any feedback you would like to give us.

APPENDIX C



Participant Consent Form

DEPARTMENT OF COMPUTER SCIENCE

You are invited to participate in a research study entitled: Tower of Questions-Gamified Testing to Engage Students in Peer Evaluation

Researcher(s): Nafisul Islam Kiron, Graduate Student, Department of Computer Science, University of Saskatchewan, ni.kiron@usask.ca

Supervisor: Julita Vassileva, Department of Computer Science, jiv@cs.usask.ca

Purpose(s) and Objective(s) of the Research:

The goal of this research is to study the students' experience with gamified peer question-answering or quizzing system. The study may contribute to general research area of Persuasive technology (PT) design in Education, Learning and Testing. To achieve this, we have designed two surveys of 10-15 minutes that we need you to respond to and use our quizzing system. One of the two 10-15 minutes questionnaire will be presented to you after agreeing to participate in the study. The access to the quizzing system and the post study survey will be given to you later.

Procedures:

- We have developed a gamified web-based question-answering system. The system allows students to create challenges (new questions) that they can pose to other students, who can attempt to answer these questions. The system uses game mechanics such as points, leaderboard, penalty and aesthetics. To use the system the students are required to log in using the credentials provided to them at the beginning of the study. The students will use pseudonyms and will remain anonymous to each other. They will design and pose questions related to the material they are learning to other students using the system. Points will be awarded to them for posing questions and answering other student's questions correctly. There will be a pre and post study survey to collect feedback, demographic data. Data about the usage of the system will be collected (e.g. number of questions posed, number of answers suggested, number of questions that got correct answers, etc.). Excerpts of student comments from the

questionnaire may be used in study, presentation and publications without disclosing identity.

- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Potential Risks:

- There are no known or anticipated risks to you by participating in this research.
- A student will be terminated from the study if they drop out of the course during the study or is found to be engaged in any unethical activities that might affect the study.

Confidentiality: (see consent guidelines section 9)

Participants will receive unique IDs in our study, and pseudonyms to use in the game that they will be using during the study. Only the researchers will have access to the mapping table between the IDs, the pseudonyms and the NSIDs of the students. When final grades of the class are in, the mapping table will be deleted and there will be no link between the real IDs of participants and their data.

A university endorsed tool, Survey Monkey, will be used for administering the survey. The data collected will be stored safely at Canadian Survey Monkey server and Researchers' computers.

Right to Withdraw:

- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on your position [e.g. employment, class standing, access to services] or how you will be treated.
- In case you wish to withdraw from the study, please talk to your course instructor during the study.
- Your right to withdraw data from the study will apply until the end of your course's term. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up:

- To obtain summary of the results from the study, please contact the researchers.

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent:

ONLINE CONSENT

By pressing the “I Agree” button below indicates that you have read and understood the descriptions provided; You have had an opportunity to ask questions and your questions have been answered. You consent to participate in the research project. A pdf of this Consent Form will be given to you for your records.



IMPLIED CONSENT FOR SURVEYS

By completing and submitting the questionnaire, **YOUR FREE AND INFORMED CONSENT IS IMPLIED** and indicates that you understand the above conditions of participation in this study.

APPENDIX D



Behavioural Research Ethics Board (Beh-REB) 02-Jun-2021

Certificate of Re-Approval

Application ID: 101

Principal Investigator: Julita Vassileva

Department: Department of Computer Science

Locations Where Research

Activities are Conducted: 1. In classroom 2. Online, Canada

Student(s): Jennifer Just
Kiron Kiron
Mina Mousavifar
Zakiya Arif

Funder(s):

Sponsor:

Title: Tower of Questions-Gamified Testing to Engage Students in Peer Evaluation

Approval Effective Date: 16-Jun-2021

Expiry Date: 16-Jun-2022

Acknowledgment Of: N/A

Review Type: Delegated Review

* This study, inclusive of all previously approved documents, has been re-approved until the expiry date noted above

CERTIFICATION

The University of Saskatchewan Behavioural Research Ethics Board (Beh-REB) is constituted and operates in accordance with the current version of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2 2014). The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this project, and for ensuring that the authorized project is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

ONGOING REVIEW REQUIREMENTS


In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month prior to the current expiry date each year the project remains open, and upon project completion. Please refer to the following website for further instructions: <https://vpresearch.usask.ca/researchers/forms.php>.

***Digitally Approved by Diane Martz
Chair, Behavioural Research Ethics Board
University of Saskatchewan***

APPENDIX E

PERMISSION TO USE RESOURCES

permission to use ToQ images 📎 1 ▾ 🗑

 **Kiron, Kiron** 📎 👍 ↶ ↷ ⋮

To: Arif, Zakiya Mon 8/23/2021 12:53 AM

Cc: Vassileva, Julita

Hi Zakiya,
Thank you for the letter.
Yes, you can use the figures mentioned in the letter.
Here is a short reading on how to cite figures/tables in your manuscript.
<https://www.enago.com/academy/tips-for-citing-figures-and-tables-in-a-manuscript/>

Hope that helps. Best regards.
Nafisul **Kiron**

Dear Nafisul Kiron,

I like to get permission to use figure numbers 1 and 2 from your paper titled " Engaging Students in a Peer-Quizzing Game to Encourage Active Learning and Building a Student-Generated Question Bank" in my paper "Effectiveness of mobile or web version of the educational game during lockdown" (tentative title).

Please let me know if I can use the resource mentioned above.

Zakia Arif

Dear Nafisul Kiron,

I like to get permission to use the image of the login page of the TOQ web version in my paper


Please let me know if I can use the resource mentioned above.

Zakia Arif

APPENDIX F


Towers That I Ruled by Territory

Algorithms	Abstraction	Introduction to Processing	Functions
Colour in Processing	Interaction and Events	Variables and Expressions	Functions with Outputs
Libraries	Conditional Branching	Repetition	Nesting Programming Constructs
Lists	File I/O	Dictionaries	Advanced Problem Solving




Type: True/False

If there are `w` items in a list, the last element has the offset `w`




Type: True/False

A while-loop whose loop condition can never become True is an infinite loop



Type: MCQ

When we do something for each element of a sequence, we say that we are _____ over the sequence.



Type: True/False

There is a limit to how much nesting you can do with conditional statements

Figure F.1: Creating Towers on Web

Log Book

Legend

-
- Success means you attacked it successfully.
- Failed means you failed to attack it and someone else conquered it.
- Closed means you failed to attack it and it is open for others to conquer it.

#	Question	Attempt	Date
1	To write a dictionary you must use which brackets?	Success	2019-11-27 19:35:10
2	Lists can't be used as values for key-value pairs.	Success	2019-11-26 21:02:14
3	Can you have more than one dictionary pair with the same key name?	Failed	2019-11-26 21:00:20
4	What is the delimiter in the file line 1,2,3,4,5,6?	Success	2019-11-26 20:49:51
5	In tabular files, all data items on a line must be the same.	Success	2019-11-26 20:49:21
6	You can write different types of data (ex. strings, ints, etc) to files	Failed	2019-11-26 20:45:24
7	What number is associated with the first item in a list?	Closed	2019-11-26 20:45:11
8	Which of the following lines of code successfully opens the file my file.txt for reading?	Closed	2019-11-26 20:45:00
9	<code>f = open("mytxtfile.txt", "r")</code> what does "r" mean	Closed	2019-11-26 20:44:41

Figure F.2: Logbook for Web version

APPENDIX G

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
sqrt_active_user	Equal variances assumed	.808	.378	.832	22	.207	.414	.37400	.44947	-.55814	1.30614
	Equal variances not assumed			.832	17.740	.208	.416	.37400	.44947	-.57129	1.31928
sqrt_app_tower_created	Equal variances assumed	1.431	.244	3.422	22	.001	.002	3.03050	.88549	1.19410	4.86690
	Equal variances not assumed			3.422	17.089	.002	.003	3.03050	.88549	1.16301	4.89799
sqrt_tower_solved	Equal variances assumed	.607	.444	-3.760	22	<.001	.001	-2.82154	.75033	-4.37764	-1.26544
	Equal variances not assumed			-3.760	21.347	<.001	.001	-2.82154	.75033	-4.38040	-1.26268