Evaluation of GTI Modules Based on Usability and Likeability

Sarika Rajeev, Sharad Sharma
Department of Computer Science
Bowie State University
Bowie, MD 20715, USA
Email: rajeevs1027@students.bowiestate.edu, ssharma@bowiestate.edu

Abstract

The game theme instructional (GTI) modules endeavor to increase the students interest in learning programming concepts. However, the GTI modules should be usable and likable to include it in a class curriculum. In this paper, we present the evaluation of GTI modules centered on usability and likeability. The GTI modules can be used as a supplement to teach linked list and binary tree data structure to computer science undergraduate classes. The GTI modules adopted the constructive learning approach and are developed using a gaming metaphor. We have incorporated a virtual instructor to help the users learn linked list in the modules. We have evaluated the GTI modules using User Engagement Scale(UES), Theory of Reasoned Action (TRA), and Science Motivation Questionnaire (SMQII) to evaluate usability, likability, and motivation respectively. The result of evaluation shows that the modules are usable, likable, motivational, and engaging.

Keywords—virtual reality, game theme-based learning, TRA, UES, GTI

1. Introduction

Game theme based learning aims at increasing the learner's motivation and engagement towards learning. Many researchers indicate that students are actively engaged in learning when they use game theme-based instructional modules [1,2]. There will be considerable improvement in learning outcomes when we use game theme-base instructional (GTI) modules as a supplement for learning [3]. According to Homer [4], game-based learning has psychological foundations which include: (1) cognitive, (2) motivational, (3) effective and (4) sociocultural. Papert's [5] states that when the students use the constructive approach of learning, they acquire knowledge through experience. The GTI modules can be included in the regular class curricula, only if they are usable and likable [6]. Despite the popularity of virtual reality games, many adolescents are not familiar with virtual reality-based gaming modules. The virtual reality-based games are attractive (likable), but they have a complicated user interface. So, usability is a primary concern for virtual reality based educational gaming module. On the other hand, if we include the educational content in the gaming modules, they will start losing their attractiveness (likeability). So, it is critical to include usability and likeability in the GTI modules together will the educational content. There are also numerous researches who have been done empirical evaluations on usability [7,8].

We have incorporated User Engagement Scale (UES) for evaluating and measuring the user engagement in the GTI modules. UES is a survey which has 31 items, and it is categorized into six dimensions of engagement: aesthetic appeal, focused attention, novelty, perceived usability, felt involvement, and endurability [9]. The UES has been incorporated by various researchers in the digital domain to evaluate the user engagement or usability of digital media and video games [9,10]. Likeability of software applications has also been evaluated using UES [11]. Zaman [12] has used laddering method to evaluate the likability of games with children. We have also incorporated Theory of Reasoned Action (TRA) for evaluation of likeability of the GTI modules. Fishbein and Ajzen [13] have stated that theory of reasoned action is a leading theory of social psychology which can be used to establish a relationship between attitude, behavior, and intention of users towards a product or technology. We have developed a questionnaire based on TRA framework and empirically evaluated the survey results for finding the relationship between familiarity with virtual reality games and the likability of the GTI modules. modules.

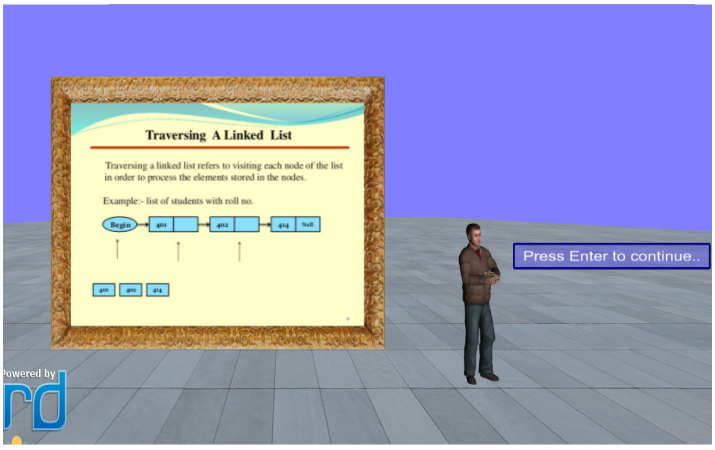

Fig.1: Virtual Instructor in GTI module for teaching linked list

Due to lack of a good framework for the evaluation of the effectiveness in GTI modules, there is the barrier for the inclusion of GTI modules in the regular class curricula. For the design and development of GTI modules to teach linked list and binary trees, we have incorporated a proven four-dimensional framework with minor extensions. Sara and Oliver suggested a four-dimensional framework (FDF) to find the effectiveness of

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game or simulation-based learning [14]. As the name suggests, FDF has four dimensions which include: (1) Context, (2) Learner' specification, (3) Pedagogic consideration and, (4) Mode of representation. The context for GTI modules is undergraduate and graduate students. We have developed the GTI modules for the undergraduate students to learn introductory programming concepts, but it can be incorporated in graduate classes too. We have also incorporated the constructive approach of learning as pedagogic consideration for GTI modules. Mode of representation for our instructional modules includes: immersive and highly interactive. We have also included a virtual instructor. The virtual instructor is continuously visible on the screen (refer fig.1) and aids the students in learning concepts. The result of the evaluation indicates that the GTI modules are usable and likable. So, we can include the GTI modules as a supplement in undergraduate classes of introductory programming.

2. Related Work

2.1. User Engagement Scale for evaluation of usability

Usability of a software is more critical than the user satisfaction of the software. The usability of a software tool or application is recognized as the main component of the user experience. So, we need to measure the attitude of a user towards the software before acceptance of the software. It is very challenging to evaluate the usability of the software. There are various methods used for evaluating the usability of the software's [7,8]. Several researchers have developed questionnaires for the evaluation of user engagement. Jacques's survey [15] to evaluate engagement (SEE) consists of 14 items and, based on six attributes of user engagement such as attention, motivation, controls, time perception, attitude and, needs satisfaction. Webster and Ho [16] questionnaire consist of two questions based on (1) engagement and (2) influences the engagement measure. Also, there were 15 questions based on the presentation medium for user engagement. Brien [17, 18] built a UES questionnaire while incorporating the Jacques and Webster questionnaire. She added more attributes to UES from her review and interview study. UES was built using an iterative method of evaluation and scale development which involved: a collection of data, assessing the validity of data, and performing two online surveys in the digital domain. The first survey had 124 items and the second survey had 40-50 items. The result of both survey, after factor analysis, concluded a self-report system had 31-items that comprise six dimensions. The usability of UES for measuring user engagement has also been examined [19,20]. The user engagement scale has six dimension which includes: includes:

1. focused attention (FA)
2. felt involvement (FI)
3. novelty (NO)
4. endurability(EN)
5. aesthetics (AE)
6. perceived usability (PUS)

According to Brien [21,22], the UES can be used to investigate user engagement for a variety of digital domain such as: (1) online news, (2) online video, (3) education (4) information search, (5) social networking and, (6) video games.

2.2. Theory of Reasoned Action for the evaluation of Likeability

In 1967, Fishbein introduced a new terminology Theory of Reasoned Action (TRA). In 1975 Fishbein and Ajzen [13] refined and developed TRA by defining a relationship between behavior, attitude, subjective norm and, self-efficacy. Many researchers have used TRA for evaluation of human behavior in the social psychology studies [23]. Shih and Fang [24], recreated the TRA and expanded it to examine the attitude and subjective norm factors which influence the endorsement of internet banking. According to Lam, Cho, and Qu [25], there is a relationship between the acceptance of information technology by hotel employ and their IT-belief, attitude, subjective norm and behavioral intention.

Many researchers have used TRA for determining the relationship between the attitude of audience and familiarity with the product or technology [24, 26]. Teo and van [27] argued that in the TRA, performing a behavior leads to a desirable outcome. So, when we try to assess the immediate response of the behavior, we only need to worried about the attitude, intention and subjective norm toward the specific behavior. Nguyen and Choudhury [28] used TRA (belief-attitude- intension model) to find the brand likability. They mentioned that there is a relationship between the familiarity of the brand and the likability of the brand product. They state that the purchase intention or attitude towards likability is directly related to the familiarity of the brand. Mishra and Akman [29] have also described that TRA provides an essential conceptual description of adoption of green information technology. The TRA model proposed that the belief will affect the attitude towards the intention or behavior (likability) towards the product or technology.

3. Experimental Design of GTI Modules

This section discusses the design and planning of GTI modules. We have developed two distinct GTI modules: (1) To teach the linked list concept and, (2) To teach binary tree concepts. In this section, we will discuss a brief overview of the design and development of both GTI modules, and in the next section, we will discuss the methodology we have used to evaluate the GTI modules.

3.1. Deployment Diagram for GTI modules:

The GTI modules were developed using Vizard toolkit. Vizard is a virtual reality software toolkit, which is used for creating, rendering and, deploying 3-D visualization and simulation application. Vizard supports various hardware devices including a head-mounted display, data gloves, cave, oculus rift, and gamepad. A deployment diagram illustrating the deployment of GTI modules is shown in Fig. 2. The GTI modules are implemented using the Vizard IDE on the

developer's side. The source code for the Linked list module and Binary tree module are implemented in python. Python is used as a programming language in Vizard. Python has robust open source libraries and toolkits. The source codes for binary trees and linked list are indicated as binary tree.py and linkedlist.py respectively in fig. 2. We have generated executable files for those two modules. Finally, these executable files can run as standalone programs on the user's side as shown in the fig.2.

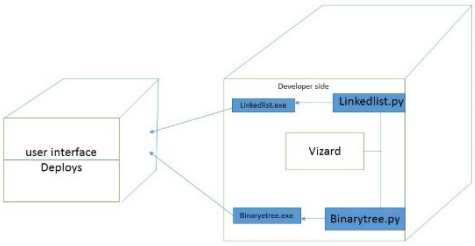

Fig. 2. The deployment diagram of GTI modules

3.2.Design and implementation of GTI module to teach linked list

GTI module to teach linked list was developed using Vizard toolkit. The instructional module was developed in two phases: (1) In the first phase, the 3D model was developed using 3D max and sketch up, (2) In the second phase, the 3D model was imported in Vizard and applied game mechanics in the 3D environment using python source code. The linked list instructional module is comprised of three level of games: one teaching introduction of a linked list, another teaching functions of the linked list, and a third one teaching the concept of the doubly linked list. When the user selects a topic/game, it starts in five seconds. Then the game begins with a tutorial on the game's topic. After the tutorial, the users are asked to complete the activity based on the related topic. If they do the activity/challenge correctly, then they can proceed to next challenge. In the first game, users get an experience of creating a simple linked list. We have used the train as a real-life example to show the creation of a single linked list. Then the user can click on next button to go to the following screen where he can experience the creation of the circular and doubly linked list. The user can exit from the game by clicking on "end" button.

Fig.3. Insertion in the linked list.

In the second game, the user gets an experience of functions of a linked list. The user can add/insert (refer fig.3) an element (a car) in the linked list (a train). The user can also visualize the deletion and search process of a linked list. The user can click on "end button" anytime and exit from the game. In the double linked list game, users get quizzes/challenges/activities based on the concepts of the doubly linked list. They can proceed to next screen/challenge by clicking on next button. They can exit from the game using end button. When they click on end button, they will reach to the main menu screen.

3.3.Design and implementation of GTI module to teach binary trees

GTI module to teach binary tree is a virtual reality-based educational tool, and it was implemented in python language using Vizard toolkit. The binary tree instructional module was also developed in two phases: (1) In the first phase, the 3D model of binary tree was developed using 3D max and sketch up, (2) In the second phase, the 3D models of binary tree were imported in Vizard, and a code was written in python language to make the virtual environment interactive. We have included a pseudo code to provide a high-level view of each game or challenge. The code will be highlighted in pseudo code when the students proceed to complete the challenge (fig.4).

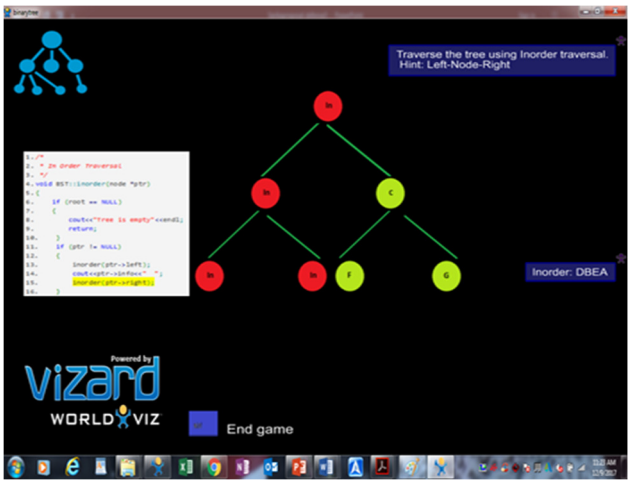

Fig.4. Inorder traversal in binary tree

There are three levels of the game in the binary tree instructional module:

1. The first game is based on the terminologies of the binary tree such as parent node, child node, left or right subtree, full tree and complete tree. There is scoreboard on screen. When the students complete a challenge, the score will be increased by 50 points.
2. The second game is based on functions of the binary tree which includes: (1) insertion in binary tree, (2) deletion, (3) search and (4) traversal of the binary tree. For the traversal of the binary tree, the students will need to accept a challenge based on three types of the binary tree such as preorder traversal, inorder traversal, and post-order traversal. The fig. 4 shows a challenge to traverse the binary tree using inorder traversal. If the students click on the nodes in using inorder concepts, it will turn green to red and corresponding string will visible on the screen. They can end a game at any time using "end" button and proceed to main menu page of GTI module. There is also a steady virtual instructor on the screen. If the students need help, they can click "help" button and ask for help.
3. The third game is based on the fundaments and concepts related to the binary search tree. We have included a reallife example "dictionary" inside the module to make the concept visually evident to the students or end users. The concepts of binary search trees include the insertion and deletion in binary search trees. There are three cases for insertion in binary search trees. For each case of insertion we have included a challenge in the game. We also included a challenge based on all cases of deletion of binary search trees. A high-level view of concept (pseudo code) is continuously visible on the screen when the students proceed the code will be highlighted per their action.

4. Evaluation of GTI module based on usability and likability

Evaluation of GTI module was done in two phases. The first phase of the evaluation done in summer 2017 semester (N=14). In the evaluation, GTI modules were assessed (during early implementation) to provide information about how to revise and modify the GTI modules for improvement. We have collected the suggestion/comments from the users and applied improvements in the GTI modules. The second phase of the evaluation was done in spring 2018 semester (N=57) using pre- and post-survey. In the final study, we have used proven survey/scale such as (1) User Engagement Scale (UES) for evaluation of usability of GTI modules and (2) Theory of reasoned action (TRA) for evaluating likability of GTI modules. The evaluation study was done after getting the IRB approval.

4.1.Study phase one for evaluation of GTI modules

During the first phase, the GTI module to teach binary tree was evaluated in the summer semester (N=14). This evaluation is fully described in our previous paper [30]. The students were asked to use the GTI modules and complete a post-survey after interacting with the GTI modules. The initial results indicated that GTI module to teach binary tree is motivating and engaging. In the post-survey, there were few questions based on usability and likability of GTI modules. The survey results showed that students did not face any technical difficulties. So, the GTI modules were usable. Also, the survey study indicated that the students felt that the module was attractive; which shows the GTI module were likable during the first phase of our evaluation. After getting student's feedback from the first phase of the study, we made improvements and modifications in the GTI modules.

Based on student's feedback, we made modifications to the GTI modules for teaching linked list and binary tree. We removed some bugs that were found in the module. We also added a steady virtual instructor in the GTI modules to teach binary trees and linked list. The goal of the virtual instructor to act as a constant companion and help and assist the students at each level during the gameplay.

4.2. Final Study of evaluation GTI modules

The phase two study was conducted in the spring 2018 semester (N=57) with the graduate and undergraduate students of computer science. All participants were enrolled in the introductory programming classes. In the evaluation process, we first demonstrated the GTI modules to all participants. The participants (M= 36, F= 21) interacted with the linked list and binary tree instructional modules. When the students started the GTI module of the linked list, they were greeted by the virtual instructor (refer fig. 5). After completing the module, the students were asked to complete a questionnaire (post-survey) based on UES (for evaluating the usability of GTI modules) and TRA (for evaluating likability of GTI modules). The study

lasted for approximately 25-30 min. The students needed minimal technical support during the evaluation of the GTI modules.

Fig.5. A 3D-avatar who greeted and introduced the GTI module.

As mentioned earlier, we have used User Engagement Scale (UES) for the evaluation of usability of GTI modules. The design of our study was distinguished from indigenous UES in two ways such as: (1) It examined game theme-based instructional modules rather than online shopping. So, it required adaption of scale in a different domain. (2) This study was done in a classroom-based or lab-based setting rather than a field study. The students completed the questions using the five-point Likert scale that ranged from "Always" to "Never." The questionnaire consisted of 31 items (questions) based on the usability of GTI modules. These questions (31 items) were separated into six subscales which included: (1) focused attention (FA), (2) felt involvement (FI), (3) novelty (NO), (4) endurability(EN), (5) aesthetics (AE), and (6) perceived usability (PUS).

Also as mentioned earlier, we have used Theory of Reasoned Action (TRA) for evaluating the likability of the GTI modules. We have created the questionnaire based on TRA using belief-attitude-intension model. We have examined the relationship between the likability of GTI modules with the familiarity of virtual reality game. There were several questions based on the familiarity with other virtual reality games. After empirical evaluation of questions based on familiarity (experience) with virtual reality games, we divided the participants into three categories of a player such as (1) novice, (2) intermediate and, (3) experienced. Then we used ANOVA test for three categories of participants for testing two hypotheses, which included:

H1: GTI modules are more likable by the participants having greater familiarity with virtual reality games.

H2: Students spend more time with the higher level of familiarity with other virtual reality games.

We have also included a comment section in post-survey for qualitative analysis of GTI modules.

5. Result and Analysis

We have evaluated the GTI modules in the spring semester with undergraduate and graduate students (N=57). In the evaluation process, we gave a presentation to demonstrate GTI modules to the students. We have explained to them the how to use the linked list and binary tree instructional modules. After interaction with the GTI modules, the participants were asked to complete a post-survey. In the post-survey, few questions were asked about the participants' demographics such as gender, race, enrollment status and significant. The survey data showed that 63.16% were male and 36.84% were female. 98.25% students were a full-time student, and 1.75% students were a part-time student. There were several questions based on the familiarity of students with other virtual reality games. The survey data indicated that students felt motivated and engaged while using the GTI modules for learning. We have also used SMQII survey questionnaire to evaluate the GTI modules. The result of the survey indicated that 74% of students thought that GTI modules were motivational.

UES is a self-reporting questionnaire to evaluate the usability of a software tool. UES has 31 items, and it is divided into six sub-categories such as FA, FI, NO, EN, AE, and Pus. We created total 31 questions for the evaluation of GTI modules based on UES. We again used a five-point Likert scale ranging from "Always" to "Never". The survey data showed that the mean value for all the six categories of UES ranged from 65.4% to 69.9% (refer fig. 6). So, the majority of the students thought that GTI modules were usable.

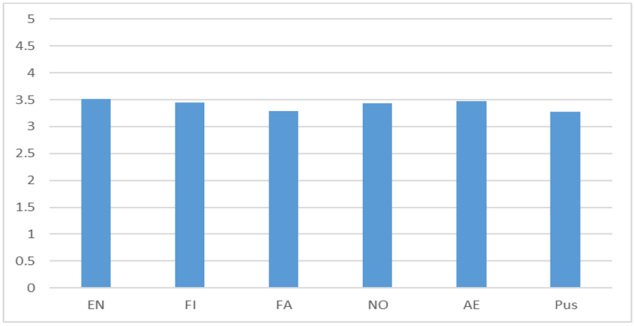

Fig.6. Mean value for all the six categories of UES ranges

In general, TRA suggests that greater familiarity with product or technology will leads to higher likability. For the quantitative evaluation of Likability, we divided the students into three categories based on their familiarity with the virtual reality games such as novice, intermediate and expert player of virtual reality game. We did ANOVA test on three categories of students based on two hypotheses: (H1) greater the familiarity tends to more likability; and (H2) the participants having more experience with virtual reality.

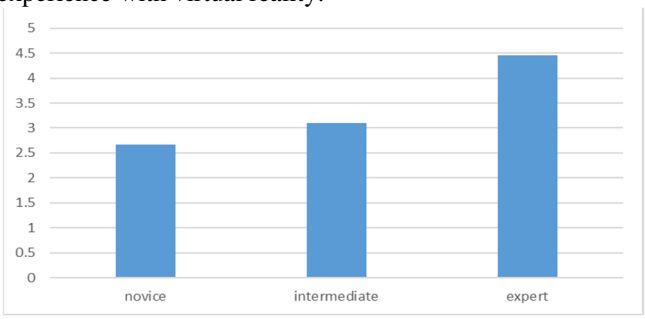

Fig.7. Mean of the likability with all three categories.

For Hypothesis 1, the results show that the likability of the expert user of virtual reality games is highest among all students. The mean of the likability with all three categories is shown in Fig. 7. The ANOVA test that we performed shows that the difference was statistically significant ($p = 6.74E\text{-}11 < 0.05$). So, the results support our first hypothesis, concluding that greater familiarity results in more likability.

Regarding hypothesis 2, the result showed that the participants who were more familiar with virtual reality game spent more time with GTI modules. The result of ANOVA analysis indicated that the difference was not statistically significant ($p = 0.186 < 0.05$). Although expert players spent more time with GTI modules the difference of time was not significant. So, our second hypothesis was wrong. Most of the students spent the time to interact with GTI modules and enjoyed the new mode of learning.

6. Conclusion

We have designed and developed two GTI modules which include: (1) to teach binary trees, and (2) to teach linked list. We have evaluated the GTI modules during the spring semester with 57 students (42 undergraduate students and 15 graduate students). We have used a questionnaire based on UES and TRA for evaluating the usability and likability of GTI modules. We have also used SMQII questionnaire to evaluate the motivation of students towards learning while they used the GTI modules. The result of the survey indicates that students felt motivated and engaged in learning. The result of the survey shows that familiarity with virtual reality game is directly related to the likability of GTI modules. The survey results showed that the GTI modules were usable. Thus, we can conclude that the GTI modules (linked list and binary trees) are usable and likable and can be included in the classroom as a supplement.

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