Game Theme Based Instructional Module to Teach Binary Trees Data Structure

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Abstract

The Virtual Reality (VR) technology has been around for years and constantly changing and expanding. In this paper, we present the game theme instructional module (GTI) centered on Model-View-Controller (MVC) architecture. The GTI module enabled in teaching computer science undergraduates the binary trees data structure concepts using gaming metaphor. We used Python for writing codes in worldviz vizard toolkit with the stand-by avatar (3D model) created as an instructor. We have developed a four-dimension classroom activities matrix-framework to help determine the effectiveness of GTI modules. The pilot study result show the GTI module when implemented in VR environment as an instructional aid gives improved learning outcomes with benefit of an engaging platform for students' creative problem solving challenges and successes.

Key words—virtual reality, game based learning, educational modules, VLE, GTI

1. Introduction

In recent years, virtual reality is securing recognition in the society and turning more pervasive in learning [1]. Dillenbourg and Schneider [2] state that the virtual learning environment (VLE) helps students to upgrade the ability to analyze the problem and understand the new concept. Many researchers conveyed that educational gaming modules are motivating and engaging. Extensive research study indicates that undergraduate students of computer programming courses do not respond good to traditional method of teaching [3,4,5]. There is need to change the traditional lecture based learning to active method of learning. Plass and Homer [6] discuss the psychological foundation of game based learning, such as: cognitive, motivational, affective and sociocultural. There are already many studies pertaining to the use of various approaches of learning, such as: XNA modules, Robotics, gamification and game theme based learning. Reynolds [7] presents a socially based game platform, which is called as Urbarium. Urbarium is developed using XNA, torque and muppets. It supports learning concepts of cs1 and cs2 programming courses. Fagin Barry [8,9] discuss the use of robot helps in teaching computer science to U.S air force . According to Kapp [10], gamification is an approach that uses game based mechanics artistic, and game thinking to engage and motivate learner to promote learning and problem solving. According to Mumtaz [11], there are several empirical studies that confirm the digital game is the main reason why the adolescents and children spend a lot of their time with the computers. So, there is rapidly increase in the software game industry. However most of these games are only for entertainment purpose. The educational technologists want to exploit games for educational purpose. Many researchers argue that software games based learning can support teaching and produce better learning outcomes. Jinghua Zhang etal., demonstrates the effectiveness of a game based module titled "Recursive Runner" that helps the students to understand the recursion in a game [12]. According to Sharma [13], game theme based instructional (GTI) modules are used as a learning tool to motivate and engage students in learning activities. There are several studies done on the use of games for education [14, 15,16]. Game theme based instructional module actively engage the learners in the learning process.

Fig1. GTI module for teaching binary trees.

In this paper, we designed and developed a game theme based instructional module to teach simple programming concepts such as: binary trees to undergraduate students of computer science. GTI module provide an intense teaching model and evolutionary learning approach. If the students use GTI modules, then the learning becomes more interactive and learners can evaluate themselves during their studies. So, game theme based instructional module permits the students to know their progress, while they are learning. The GTI module demonstrates the concepts of binary threes which include:

1. Understanding of parent node, child node, left or right

sub tree
2. Understanding of full or partial filled trees
3. Insertion or deletion of a node
4. Searching a node in a tree and
5. Concept of Binary search tree

According to Beaubouef & Mason [17], there is very minute open space for the students to work with the content of the course innovatively. This module motivates and engage the students to learn the concept of binary trees. This paper discusses a proven framework to evaluate the effectiveness of GTI module before it is implemented in the class curriculum. The initial result of the evaluation indicates that the GTI module is motivating and engaging. So, the game theme based educational module can be used as a supplement in the classroom activities and it will produce better learning outcomes. In the next section, we describe the previous work briefly.

2. Background

The learning of various method of learning and corresponding learning outcomes is thought-provoking and has led to numerous studies by various researchers trying to understand best way of learning. In trying to produce better learning outcomes, researchers have built various learning approach to motivate and engage student. A meta-research was done, that is based on four hundred and thirteen journal papers which are collected from approximately seventeen technology enhanced learning journals. The result shows that game-based learning is a booming research area after 2005 in USA, Europe and Asia. The study also indicates that game-based learning research is affected by the technology growth [18].

In virtual reality environment, there is great experience of learning. In the real world. Augmented reality based system can allow abundant multimodal learning experience by permitting the learners to manipulate the real object in physical space. Manipulating the object can help the students to more engage with the course content as it gives an extra mode of learning.

One additional benefit of game theme based learning is increase in the approachability of educational content. Learners can access educational content using computer devices such as: desktop, laptop or kiosk. In the recent years, many researchers have seen a considerable increase in interest in the subject, when game was added as a flavor for computer science students [19]. There are already many studies pertaining to the use of games for education, and most of them agree that software games provide tangible, understandable, and appealing context in learning of computer science [20, 21,22].

2.1.Adopting VR educational games in learning

According to Chang and Medicherla [23], the virtual and augmented reality can enhance the motivation of learning and strengthen the realism based application of the learning concepts. Due to improvement in computer and information technology, the virtual reality system in education and training is believed to have more inspired learners. The system also promises to attract learners in acquiring new concept using the

diversity of various perspective of virtual reality system. According to Kerawalla et al [24], the augmented reality system is developed in 1960's but its pragmatic employment in education and training is started in recent years. Kerawalla emphasize that, when we use the augmented reality in education, the learner gets more motivated and engaged in inventing the resources and applying them in the real world [24]. In 2016, IEEE took an initiative Focuses on Augmented Reality, Virtual Reality, and Human Augmentation technologies. According to Yuan, the next generation of technology will include AR and VR to create virtual world which will be so real and provide an ultimate experience [25]. Chaffin and Doran designed a game that helps to learn programming and they also demonstrate the impact of games on learning [26]. According to Morreale et al [23], there is an augmented reality application which is known as 'construct3D'. construct3D was designed to learn mathematics and geometry. This application uses three-dimensional geometric constructional model [27,28]. This application permits multiple users to share the virtual space. The users can construct geometrical shape by wearing head mounted display. It also enables the learners to inlay the computer generated virtual object in the real world. Jean and Carran provide a description of a game based learning environment "The Pedagogical Dungeon". They also briefly describe the link between the learning activities and the objects of Dungeon [29]. In the next section, we discuss various methods which are used to evaluate the educational games.

2.2.How to evaluate educational games

Educational software games aim to develop students as successful learner. However, the computer games are not included in course curriculum of school until they are evaluated useful for majority of students. Sara and Martin [30] propose a method to effectively evaluate the learning with games and simulation. The attempt to add educational games in school curriculum is not triumphant yet. There are several reasons for this. One of the prominent reason is that neither all instructor nor all parents are convinced with the effectiveness of educational games. Other main reason is that still there are criticisms about the usability and likability of existing educational games. For example, according to Brody [31], the marriage of education and game like entertainment are neither educational nor entertaining.

There have been several attempts to introduce framework to help instructors to evaluate learning outcomes based on technology. However, the lack of successful framework has significant impact on the uptake of educational games in school classroom. Oliver [32] points out the TILT, CIAO! And Flashlight framework are used in the evaluation of teaching which is integrated with technology. Freitas and Oliver, proposed a four-dimensional framework which help tutors to evaluate the learning outcomes of students based on the learning with games and simulations. In this framework practitioners consider four main dimension before using games in their practice. This four-dimensional framework is considered as iterative and shows a method of evaluation that an instructor should consider before the evaluation of learning outcomes, where learning is based on games and simulation

[30]. In the next section, we will discuss the usability and the likability of the educational games.

2.3. Usability and likeability of educational games for adolescents

According to Maria and George the educational games can be included in school classroom only if it is usable and likeable by all students. Fabricatore et al. [33], did research for the likeability of games, which are not necessarily educational games. Few studies are done to categorize the games player or user. For example, Tsai [34], disclose that there is notable difference between the boys and girls in enthusiasm of game playing. This was true for other categories of children too, not only the boys' and girls' categories. Thus, not all children like the computer game at same extent. If the likeability of the gaming software is very low for most of the targeted players, then there is no use of using educational games in classroom. Usability can also affect the likeability of software games. If the software game is not useable then it may be less likable. There is one good example, if the students feel the game difficult to play or interact, then they may dislike the game. So, if the educational game is not likable by the students then it will cause problems instead of helping the students when we include these games in their regular curriculum. The evaluation of educational games considers usability of educational games. Usability is one of the important issue that we used to analyze for the evaluation of GTI Module. According to Yacci, Haake, & Rozanski [35], the edutainment environments, require few efforts that are not needed for the instructional goals. Thus, they point out about usability of software, they ask that it is very important to analyze whether the effort done by students to understand game is gainful or not. We therefore focused on the fact that GTI are enjoyable enough to wear and use. In addition, usability and likeability characteristics of GTI module meet the end-user (student) requirements.

3. Design requirement of Game Theme based Instructional module

This section discusses the design and planning of binary tree instructional module and a brief overview of the framework which we used to find the effectiveness of the game theme based instructional module.

3.1. Design requirements of GTI modules: - functional and non-functional

The GTI Module-problem task followed the revised 'Bloom's Taxonomy' to help evaluate students' understanding of the concept. The revised Bloom Taxonomy outlined problem solving performance success levels such as: understanding, analyzing, remembering, evaluating and creating. The GTI module is centered on constructive approach of experiential learning theory. In constructive approach of learning, the learners acquire knowledge through active experience that is vital in GTI module implementation process. In the design of GTI instructional module, we consider both the functional and non-functional requirements as outlined below.

The functional requirement includes:
- The instruction should be clear and concise. So, the students can easily understand the instruction and do not waste their time in navigating through the GTI modules.
- The module should be likable by the students. The GTI module should be designed more interactive and enjoyable.
- The module should be usable. So, the students do not face any technical difficulty while interacting with the module.
- The pseudocode of binary tree should be displayed on the screen. The goal is to provide the learners high level view of fundamentals of binary trees.

The non-functional requirements include:
- The GTI modules should motivate and engage the students in learning binary trees concepts. The pseudocode and figures presented in the GTI module should encourage students to learn more about binary trees.
- The GTI modules should be platform independent. The students can use these modules on any platform which is available to them.
- The module should be less distracting. The examples should be related to binary tree concept. So, the students don't distract from the actual matter.
- There should be a rewarding system in the GTI modules. The students should be rewarded with a scoreboard. So, the students can evaluate themselves during the learning process.

3.2. Framework to find the effectiveness of GTI modules

Due to lack of a good framework there is impediment in implementing game theme based learning in class curriculum. So, there is need of useful framework to find the effectiveness of the GTI modules.
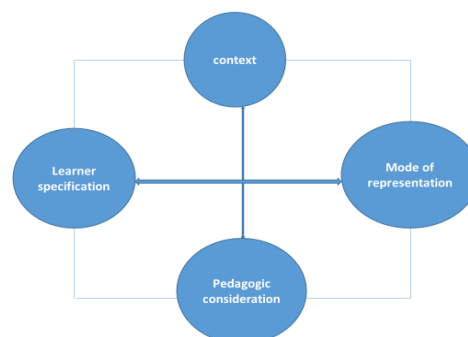

Fig.2. framework for finding the effectiveness of GTI modules.

De Freatas and Sara suggested a framework, which is adopted with minor changes and used to measure effectiveness of GTI module and simulation based learning [30]. The framework inherits the primary triad: students, teachers and the tools. The fig. 2 represents an iterative cycle which is used as framework to evaluate the effectiveness of game or simulation based learning. In this framework, there are four main dimensions which we considered before implementing the GTI modules in the classroom activities. The first dimension of the framework emphasizes on the specific context, where the learning takes place. The context includes classroom based, outdoors, access to various equipment, historical or political factors and technical support. The second dimension of the framework emphasizes on the attributes of learners. This includes the profile of learners, learning background and the group profile. The third dimension of the framework emphasizes on mode of representation which includes level of fidelity, interactivity with the software and immersion. The fourth dimension of the framework emphasizes on the methods of learning during the class curricula and during the simulation based learning. This dimension of framework reflects upon the learning theories, learning approaches and learning models to support better learning outcomes.

The framework shown in fig.2 can be represented in checklist style as demonstrated by table 1. Using this table relation between context and GTI module is analyzed. This table can be used by the instructor before the game and simulation based learning is applied to the class curriculum.

Table 1: checklist to find the effectiveness of GTI modules

Context	Learner specification	Pedagogic consideration	Mode of representation
CS students in under graduate classes.	Undergraduate students from computer sc. Dept.	involves constructive learning theory. learners construct knowledge for themselves.	Using non-immersive 3D interfaces.
Classroom based and computer lab based	support students with different learning style.	Learning outcomes would support the student to learn programming concepts.	Have high level of interactivity.
Immersion and interaction in learning environment.	The game can be used by the students working individually.	Learning activities for this game emphasis on the clarifications of the concept for the better learning outcomes.	Learning outcomes are achieved partly by the playing game and partly by the interacting with the virtual instructor.
Limited technical support and resources are needed to play the game.	The tool doesn't support group study.	Briefing/debriefing should have been implant into the game to achieve learning outcomes and motivate students to learn more.	Learning activities and outcomes achieved through the game based instructional module.

4. Implementation of GTI module

The development of GTI modules is aimed to demonstrate the concept of fundamental of binary trees. This section discusses the various aspects of implementation of the GTI modules such as: MVC architecture, Immersive and non-immersive feature of modules.

4.1.MVC Architecture

Game theme based instructional module to teach binary tree was developed using worldviz vizard toolkit. Vizard is an integrated development environment (IDE) and it is used for creating, rendering and deploying virtual reality application. Vizard build a virtual world that can be deployed everywhere. We used python for writing code in Vizard. Python is world's most approachable scripting language. It has robust open source libraries and toolkits. 3D models of the GTI modules was created in 3D-max and imported in vizard. Then the 3D models are scaled to fit in the virtual environment created in vizard. With the stand-by avatar (3D model) created as instructor, students are able to know the introduction of binary tree and navigate through the GTI modules. First the instructor introduces the concept then the student clicks on 'space bar' to start the game.
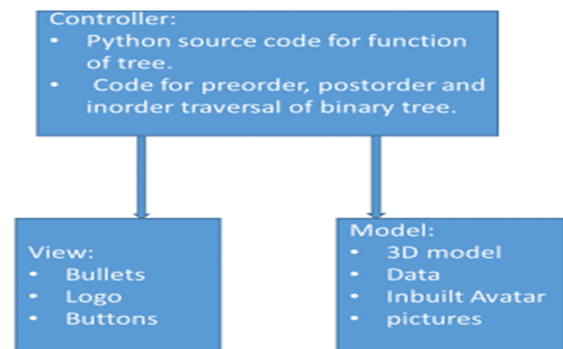

Fig. 3. Shows the MVC architecture used in the GTI module.

We use Model-View-Controller (MVC) architecture for the development of game theme based instructional (GTI) module.

- Model is the central component and maintains the data of the application. In GTI module which we have developed the 3D model, inbuilt avatars, pictures and data are the model.
- View is a user interface. In this GTI module the bullets, logo, buttons are view. These views are displayed to the users using model and the users can modify view using controller.
- Controllers handles the user's request. In GTI module which we have developed the python source code is the controller. So, the students interact with the view and manipulate the view as required.

4.2. Immersive and Non-immersive GTI modules

The objective of virtual reality based games is to provide the users a 3D environment in which the students interact

with the virtual world. There are two types of virtual reality based games, immersive and non-immersive. The actual virtual reality stands for full immersion using virtual reality tools such as: head mounting display, data gloves and oculus rift. The virtual reality hardware provides the users a full virtual immersion as well as six degree of freedom. The other form of virtual reality game is non-immersive. The non-immersive games also provide the users a virtual 3-D environment that can be directly manipulated. We developed the GTI modules using non-immersive virtual reality. The students can interact with game using desktop monitor, keyboard and mouse. The GTI modules can be converted into immersive virtual environment using hardware like oculus rift. The virtual reality hardwires are expensive. We can't provide these hardwires to all students in the classroom. So, we developed non-immersive GTI modules, which can be easily implemented in class curriculum.

5. Result and Analysis

We evaluated the game theme based instructional module in summer semester with interaction of undergraduate and graduate students (N=14) to GTI modules. In the evaluation process, we demonstrated GTI modules to the students. We explained them the study procedure and how to use the GTI module application. Fig.4. shows the menu of binary tree instructional module. The end user (students) can select any of these topics to learn and visualize the concepts.

Fig 4. The menu of binary tree instructional module.

A post survey was completed by all the students. First few questions of the post survey contained the queries to find user's demographics such as: student's gender, major and the programming courses they have taken or taking. 55.85% students were male and 46.15% students were female. 50% students were computer science, 42.66% students from computer technology and 7.14% students were from mathematics department. All the students have taken or currently taking a programming course. 57.14% students from COSC 113 course, 28.57% from COSC 504 course and 14.29% from COSC 561 course. The survey data shows that the GTI modules make noteworthy educational impact on the learners. The results of the evaluation show that the GTI modules runs well and met requirement set forth in the design and interest of

student's in learning the concepts of binary trees structure is increased.
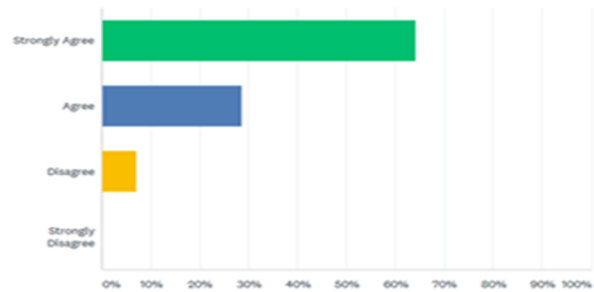

Fig. 5. Were you able to understand the code while playing GTI modules of binary tree?
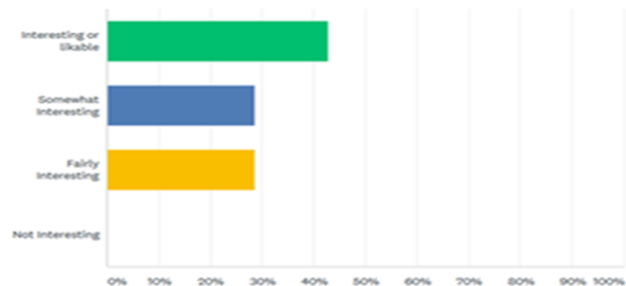

Fig.6. what do you think about GTI modules of binary tree (is it interesting or likable)?

As shown in fig. 5, 64.29% of students strongly agree that they understand the code while playing GTI modules of binary tree. Whereas, 28.57% of students agree that they got the code while they were using GTI modules. Only 7.14% of students disagree that they got the binary tree concepts while playing. Thus, the majority of the students learned various concepts related to binary tree after using the GTI modules. The survey also contained questions about the likability and usability of GTI modules. According to survey data, 42.86% of students think that the GTI module is interesting (or likable) and 28.57% of students think that GTI module is somewhat interesting. From fig. 7, we can see that there was no student who thinks that GTI module is not interesting. So, we can conclude that the GTI modules for binary trees is likable. One of the questions in survey, "Was it easy to use the menu (fig. 4.)?", was asked in regard to find the usability of the GTI module. The survey data indicates that 100% of student find it was easy to use the menu. Thus, the GTI module is usable.

The observational qualitative data shows that, the GTI module when implemented in VR environment as an instructional aid affected and deepened learning outcomes with noteworthy benefit of an engaging platform sustaining students' creativity in problem solving.

6. Conclusion and Future work

We have designed and implemented a GTI module to teach the concepts of binary trees and the modules can act as a

supplement to existing class. We have used a proven framework to evaluate the effectiveness of GTI module. We have conducted a user study with 14 students (8 undergraduate students and 6 graduate students) during summer semester. All students who participated in user study had already taken a prior programming course. The result of survey indicates that the GTI modules helped the student to learn the concepts of binary trees.

Based on the students' feedback, we plan to develop more GTI modules to teach other concepts such as linked list, arrays, or any other programming concepts that the learners struggle with. In future studies, we plan to add GTI modules in introductory programming classes as a class assignment. So, that we can introduce students to an alternate method of learning.

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