

GAME THEME BASED INSTRUCTIONAL MODULES BASED ON  
USABILITY AND LIKABILITY

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A Dissertation Submitted to the

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In Partial Fulfillment

of the Requirements for the Degree of

DOCTOR OF SCIENCE IN COMPUTER SCIENCE

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Department of Computer Science

By

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DECEMBER 2018

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## ABSTRACT

### GAME THEME BASED INSTRUCTIONAL MODULES BASED ON USABILITY AND LIKABILITY

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The goal of this thesis is to assess the motivation and learning gains of undergraduate students for game theme based learning in introductory programming courses. The objectives of this research include (1) Analyze the pathways to support learners such as pedagogic consideration and constructive approach (2) Design and develop a game theme based educational module based on a proven framework for evaluating game and simulation-based learning (3) Perform user study on GTI module to assess the attitude, motivation and learning gain of students in introductory programming courses. (4) Evaluate the GTI module concerning the usability and likability. There is a need to change the traditional passive method of teaching to an active method of teaching such as game and simulation-based learning. In the expansion of education reform, gaming is considered one of the effective tools to teach students. There is also a need to embody the educational effect of games, for combining games and learning together. However, the problem is how to use the software games in the education system. The GTI modules adopted the constructive learning approach and are developed using a gaming metaphor. The design of the GTI modules is modeled from the revised 'Bloom's taxonomy.' Furthermore, in this research, we have incorporated a proven framework with a minor extension for the design and development of GTI modules. Students were evaluated in two phases during the research study. The data were analyzed using statistical analysis methods. We have applied

proven evaluation scale/methodology for the evaluation of the effectiveness of GTI modules, which includes: (1) Student Assessment of Learning Gains (SALG) to evaluate the learning gain. (2) Science Motivation Questionnaire II (SMQII) for evaluating the motivation of students. (3) User Engagement Scale (UES) for evaluating the usability of GTI modules. (4) Theory of Reasoned Action (TRA) for evaluating the likability of GTI modules. We have performed the t-test for evaluating learning gain and motivation of students, ANOVA test for evaluating the likability based on familiarity with other virtual reality games and, grounded theory for the evaluation of usability of GTI modules. The result of evaluation shows that the GTI modules produces better learning gain and; are usable, likable, motivational, and engaging.

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## DEDICATION

I would like to dedicate this dissertation to my father, Mr. Baidyanath Pd. Singh, my mother, Mrs. Rashmani Singh, and my dear husband, Mr. Akshar Rajeev. My parents provided constant advice, encouragement, and help, which truly helped me in the completion of this long journey. My husband provided guidance and fantastic insight, which helped me in the completion of this academic voyage. Finally, I would like to dedicate this dissertation to my kids, Anika and Aniya Rajeev. Their curiosity in exploring and learning new things hearten me in furthering my research for the dissertation.

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# CHAPTER 1

## INTRODUCTION

### 1.1. Problem statement

With the fast development of computer science and technology, the computer games become one of the essential parts of living, especially for the youngsters. Research studies have conveyed that educational games are motivating, engaging and provide reliable learning context. Research indicates that undergraduate students of computer programming courses do not respond well to the traditional method of teaching. So, there is a consistent decline in the number of students choosing computer science courses at the undergraduate level [1, 2]. Many computer science departments around the world are modifying their teaching methodology to teach introductory programming courses. Many researchers argue that the educational software games can support teaching and produce better learning outcomes, but they do not describe how to implement or use the gaming software in-class curriculum.

Due to the expansion of the educational transform, game theme based learning methodology has become one of the current research focus There is a need to modify the traditional lecture-based passive method of teaching to an active methodology of teaching. In recent years, digital games have become quite popular among adolescents. According, to Mumtaz [3], the software games is the one of the primary reason why children or adolescents spend their time with the computer. The educational technologist wants to exploit a digital/computer game to create a software which can be used for learning purpose. Many researchers argue that the game theme based learning has the potential to transform the learning by making the concepts more fascinating and absorbing. The objective of the thesis is to develop a game theme-based

instructional (GTI) module for teaching programming concept related to binary tree and to find the usability and likability of GTI module.

The design of the GTI module is modeled from the revised 'Bloom's taxonomy.' The Bloom taxonomy promotes the various aspect of learning such as remembering, understanding, applying, analyzing, evaluating and creating [4]. The novelty of the research is to provide an exploratory foundation into the use of game theme based learning for undergraduate students of computer science department.

The purpose of research is to motivate and actively engage undergraduate students in learning programming concept such as binary trees and the linked list to produce better learning outcomes. Advocates of game-based learning suggest that game-based learning has better positive impact on the learning outcomes in comparison to the traditional method of teaching [5,6]. There were three major categories emerged from the finding of our research study. The categories comprised of: (1) perceived challenges in traditional lecture-based courses, (2) perceived challenges in previous game-based learning, (3) strategies for creating a framework for valuable game-based learning experiences.

The game based instructional module can provide the means for a more effective approach to learning. Papert [7] argue that in constructive approach the learners acquire knowledge through experience. Furthermore, many researches have been done on the development of educational games that increase the motivation and engagement of students [5,6]. Many researchers suggest that when the learner is actively engaged in the learning process, then it is beneficial for learning outcomes. The engagement with learning promotes exploration, and conversely, exploration promotes engagement with learning [8]. However, there is no report that any of these researches were introduced in the class curriculum. Before the introduction of game theme-based

instructional module in the class curriculum, we need to examine several issues such as usability and likability of game theme-based instructional module. In other words, if the game theme-based instructional module is usable and likable by students then only we can introduce game theme-based instructional module in the classroom. These instructional modules can efficiently promote learning by encouraging the students' participation. Game theme based learning is a student-centered educational method which is driven by the students. However, a game based learning not always work efficiently, and sometimes it does not meet the learning goal. For example, when there is not enough technical support which is required by the game theme based educational modules or students have less exposure to the gaming interface, then the learning goal does not meet. Through the analysis of a proven framework, we have developed a GTI module which is more efficient and can be integrated into the classroom. The GTI modules had the course content of binary trees and linked list. This GTI module is designed to motivate and engage students in introductory programming courses.

Even though there are software games, but still there are many people who do not play games. Griffin and Hunt [9] mention that approximately 33% of youngsters play games every day, but there are also approximately the same percentage of youngsters who play games once in a month or even lesser than that. So, there is the difference in the level of expertise with the software games. This research examines if the game is usable by all the students having a different level of expertise to the computer games. For example, if the student finds difficulty in the interacting with the game theme-based instructional module, then the game theme-based instructional module is less likable. If the game theme-based instructional module is less usable and it is introduced in the classroom, then these modules might cause the problem to the students.



This research includes evaluation experiments which evaluate the usability and likability of the game theme-based instructional module. The usability and the likability of instructional gaming module can be increased by resolving specific issues. The issues include (1) technical support (2) exposure to virtual reality games (3) adding more details to the GTI modules. The result of the evaluation showed that the game theme-based instructional module is usable and likable. The statistical analysis of the usability showed that educational game is considered more likable by an expert player than intermediate or novice player.

## 1.2. Research Questions

1. Are GTI modules an effective tool for producing better learning gains? (obj. 3)
2. Are GTI modules an effective way to motivate and actively engage students? (obj. 3)
3. Are GTI modules effective in improving understanding of the concepts? (obj. 1)
4. What are the main issues to be considered in order to introduce the GTI module in the class curriculum? (obj. 1)
5. Are GTI modules usable and likable? (obj. 4)

## 1.3. Hypotheses

H<sub>1</sub>: There is a significant difference between the learning gain of students when they use GTI module to learn binary tree and linked list. (Rq 1, Obj 2)

H<sub>2</sub>: The students having more exposure to other virtual reality games are more intrinsically motivated after interacting with GTI modules. (Rq 2, Obj 2)

H<sub>3</sub>: The students having more exposure to other virtual reality games have more self-efficacy than the students having less exposure to VR games, after interacting with GTI modules. (Rq 2, Obj 2)

H4: the students had more exposure to other virtual reality games have more self-determination after interacting with GTI modules. (Rq 2, Obj 2)

H5: the students had more exposure to other virtual reality games have more “Grade motivation” after interacting with GTI modules. (Rq 2, Obj 2)

H6: the students had more exposure to other virtual reality games have more Career motivation after interacting with GTI modules. (Rq 2, Obj 2)

H7: There is a significant difference between the motivation of students when they use GTI module to learn binary tree and linked list. (Rq 2, Obj 2)

H8: GTI modules are more likable by the participants having greater familiarity with virtual reality games. (Rq 5, Obj 3)

H9: Students spend more time with the higher level of familiarity with other virtual reality games. (Rq 5, Obj 3)

H10: GTI modules to teach binary tree and linked list are usable. (Rq 5, Obj 3)

#### **1.4. Goal and Objectives**

Goal:

The goal of the study is to assess the motivation and learning gain of undergraduate students concerning game theme based learning in introductory programming courses. To assess motivation and learning gain while implementing game theme-based instructional module for programming courses in an undergraduate classroom, we have used a proven framework with minor extension. A game theme-based instructional module is designed and developed to teach the fundamentals of binary trees that includes (1) understanding of parent node, child node, left or right subtree (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 BST. The design of game-based instructional module is modeled from the revised 'Bloom's taxonomy'[4]. The Bloom taxonomy promote a various aspect of learning such as remembering, understanding, applying, analyzing, evaluating and creating.

The research work also evaluates the usability and likability of the game theme-based instructional module. The purpose of the study is to produce better learning outcomes for the undergraduate students who have taken the introductory programming course.

#### Objectives:

1. Analyze the social and subjective affordances of game theme-based instructional modules in education. (Rq4)
2. Design and develop a game theme based educational modules based on the extended four-dimensional framework and activity theory. (Rq3)
3. Perform user study for GTI module to assess motivation and learning gain of students in introductory programming courses. (Rq1, Rq2)
4. Evaluate the GTI module concerning the usability and likability. (Rq5)

### **1.5. Contributions**

1. Developing Game Theme based Instructional (GTI) modules for a binary tree and linked list based on an extended four-dimensional framework (FDF) and activity theory with an implementation in plan-driven approach.
2. The GTI modules are more usable and likable in motivating students.

3. Evaluation of GTI modules has proved that there is an enhancement in learning gain for the students when they have used GTI modules for learning the concepts.

### **1.6. Benefits of Research**

1. Motivation and engagement of students can be increased by the introduction of game theme based educational module in the classroom curriculum.
2. Making the programming concepts more fascinating and absorbing. Increase the interest of students in programming courses, so the number of students could be increased.
3. The challenges and barriers are avoided by using a proven framework, so the game theme-based instructional module is evaluated before its implementation in the classroom.
4. Successful evaluation of GTI module regarding usability and likability provides the evidence that GTI module could be introduced in classroom activities and, it will improve learning outcomes of undergraduate students who have taken introductory programming courses.
5. The GTI module could be used to train an employee in the industry who does not have basic programming knowledge, and he wants to learn it for his work.

### **1.7. Target Audience**

1. Undergraduate Students who want to learn programming concepts proficiently. However, it can be used by graduate students.
2. Education institutions who teach programming courses in their curriculum and course

materials.

3. An educational community who are focused on creating instructional modules.

### **1.8. Summary of Methodology**

The methodology explained further down in Chapter 3 will involve using the constructive approach of learning and to develop game theme-based instructional module. Then evaluate the learning gain and motivation of undergraduate students at Bowie State University in the department of computer science. Additionally, we have evaluated the usability and likability of GTI modules. We use a proven framework to validate the authenticity of the game theme-based instructional module. Once validation is complete, we have evaluated the game theme-based instructional module to test the various research questions mentioned above in section 1.2 of the dissertation.

### **1.9. Limitations of the study**

- GTI modules are developed for the non-immersive environment. However, as they are developed using Vizard (VR toolkit, IDE), they can be easily converted into the immersive environment in future.
- The sample size for phase I (summer 2017) was 14 students and for phase II (spring 2018) was 57 students.

## CHAPTER 2

### LITERATURE REVIEW

The analysis of the various methods of learning and related learning outcomes is thought-provoking and has led to numerous studies by researchers trying to understand the best way of learning. In trying to produce better learning outcomes, researchers have built various learning approaches to motivate and engage the student. Independent learning, collaborative learning, cooperative learning, powerful learning tools, and constructive learning are some of the examples of learning methods that exist today to motivate and engage the students.

#### 2.1. Instructional module for teaching a programming course

Historically there have been many types of the instructional module developed as a tool to motivate and engage students and produce better learning outcomes. These modules aid the instructors in teaching students. In the traditional method of teaching, new topics are introduced by the instructor and followed by examples or application. In recent years, teachers (instructors) all around the world are modifying their teaching methodology to teach complicated concepts. Many research suggests various modules of teaching such as XNA module, robotics module, games, and simulation-based module.

##### 2.1.1. XNA modules

Microsoft offered a professional development toolkit called XNA, free of cost in 2006. This first version of XNA was followed by 2<sup>nd</sup>, the 3<sup>rd</sup> and fourth version in 2007, 2008 and, 2009 respectively. XNA facilitates to program on graphics processing units, using high-level shader language. XNA provides the ability to develop the game in C#, to run on Xbox 360.

Researchers indicate that game development is a captivating way to motivate students to

learn difficult technical concepts such as programming, software engineering, and algorithm [10]. A game development course using the XNA platform can help a diverse group of students to learn all aspects of game creation [11]. Researchers have recognized that bringing together a heterogeneous group of student is tough. One of the main challenges in teaching computer graphics is the diversity of the students. Linhoff and Settle [12] present a method to teach computer graphics for game development using XNA as a tool. The main problem in their research was, there were the varieties of students of the different level. The course had four distinctive programming assignments, which were designed to describe the game development by connecting the debugging process with visual feedback.

Birchall [13] explores the formation of educational games intended for UK GCSE-level content called Elemental. Elemental was developed using Microsoft XNA and utilized the personal computer as well as on the Xbox 360 platform. Elemental, addresses the elements of periodic table, which is a subject with extension in physics, chemistry, and engineering. It uses a pre-and-post, test method to evaluate learning outcomes.

In late 1970, the term serious game was used to refer learning from board and card based games. In a recent concept, the serious game is an interactive media game such as a video game or a computer game, which is used for educational purpose. Serious games can expand teaching media, as it offers new ways of teaching. Many surveys have emphasized the benefits of educational gaming [14]. Reynolds and Fotouhi [15], present a socially based game platform called Urbarium. Urbarium was developed using XNA, torque, and muppets. It supports learning concepts of CS1 and CS2 programming courses. Urbarium's description extends into three different stages of social development. These stages correlate with tribal economics, hunter-gather economics and state organization [15]. The students communicate with each other over

Local Area Network. After solving the problem, students exchange their code segment and complete the component. The completed component gives an enhanced bonus to students on next level of moves, which supports a net-centric approach to software development. It also facilitates the communication between the students in a lab. Many researchers discover that social factors influence the formation and transmission of knowledge [16]. It is easy to perceive that the social context is an essential factor in determining the learning outcomes of students. The Urbarium uses a gaming environment to support learning and communication between the students. The Urbarium is a series of communal driven games, which are a part of programming labs for CS1 and CS2. The Urbarium moves in a peer-to-peer network, where students interact with each other using their personal computer. There are three basic games, (1) hunter-gatherers, (2) village formation and, (3) state formation respectively. Students of CS1 starts with the primary function of simple code component. Then village formation is introduced, and students begin to learn data structure and algorithm for the completion of tasks. In CS2, students focus more on object-oriented design and problem-solving.

Object-oriented design (OOD) and Object-oriented programming (OOP) are considered as one of the most challenging parts of introductory programming. Giordano and Maiorana [17] use an adaptable framework such as XNA to build games, which focuses on the learning of object-oriented design and object-oriented programming. This pedagogical approach is useful in the classroom with highly differentiated students. There are two main elements of this approach, a project, and an inquiry-based pedagogical method. The significance of computer programming and strain in teaching computer programming is well documented in the literature [18]. Microsoft XNA can run on multiple devices and window's mobile phone. The new generation enthusiasm for a mobile phone can be used to teach fundamentals of computer science without



compromising the devotion to teaching concepts [19]. Educational gaming becomes apparent as a powerful learning tool in the educational domain.

### **2.1.2. Robotics module**

Many research reports that students can easily understand the complex subjects such as theoretical aspects of computation, algorithmic reasoning and intelligence of machine with the help of robots. The detailed results of experiments are based on learning outcomes and feedback of students. Some universities decided to use a different method to teach basic concept of computer science. They have chosen to instruct the students with the help of robots. Kumar [20,21] mentioned that this approach helps to engage students in learning and produce better learning outcomes.

One of the research shows, how the use of robot helps in teaching computer science to U.S air force [22]. Fagin [22] asserts that the use of the robot provides an innovative and compelling way to explain the basics of computer science to air force officers. Fagin [22] introduce basic programming skills such as selection, iteration, input/output procedure, arrays, graphics, and, file processing using the robotic modules. A robot with two wheels was connected to output A and C to teach sequential control flow. The students were asked to write a program to help the robot to move forward two seconds, then play a song, then move forward for one second and stop. All program made up of procedures. While writing the program for the robot, students observed that one big problem could be reduced into the smaller procedure.

Another research was done by Kumar [20,21], using robotics for teaching artificial intelligence. The course was about introducing traditional artificial intelligence concepts, including representation and reasoning. In fall semester 2000, use of robot was introduced in the

curriculum of A.I for the first time. Then the learning outcomes were observed for three continuous years. During that period, the basic concepts of the course have remained the same; only slight alteration was done. The course includes three tasks: the first task was to do a project on breadth-first search and depth-first search, the second task was about heuristic searches and, the third task was a project to determine the character printed on the grid. The outcomes of Kumar's research indicate that robotic modules help in teaching and improve the understanding of concepts.

In another research done by Frank [23]. Students participating in this research had no experience in programming or, at the most had experience of one semester in java. In the first project, students were introduced to stimulus-response rule and how robots attain effective response. The second project reveals the student's sensitivity of the sensors to various stimulus. In the third project, students were familiarized with the navigation process. In the fourth and fifth project, the students were asked to build a robot who is playing with a ball and competing against the robot built by another team. The last and sixth project showed that it was not simple to produce control program of hardware by translating a search-based problem solver. Based on the observations from the students, Frank [23] argues that the robotic projects had more positive than negative influence on students' understanding of AI concepts. He also asserts that robotics projects had enhanced students' comprehension of the issues related to the design of "hardware and software" agents.

### **2.1.3. Maker movement**

The maker movement has collected plenty of current deliberation in the well-linked imagination. Maker culture is a method to show inventive and common move. The enthusiasm of maker movement led to an escalation of maker space in all around the world including k-12

schools, libraries, museum, and other organizations. The maker movement refers mainly to the people who are busy in innovative construction of relics in their day-to-day lives and who share the procedure and artifacts to others on physical or virtual forums [24].

According to Anderson [25], the maker movement is defined as a new industrial revolution. Anderson differentiate between maker movement and tinkerer by referring to three essential features:

- In the maker movement, there is a need for digital desktop tools.
- Maker movement has an ethnic norm of splitting design and participating online.
- There is a need of usual design standards to facilitate sharing and fast iterations.

The tools and the spirit of maker revolution propose apprehension and ambition for schools. All students seek dare and "hard fun," that encourage them to look for more information and establish great ideas. The recent and exciting maker movement is one that all instructors require to grasp. There is a different lesson that instructors require to embrace in the maker movement. They comprise of following:

- "Doing" is a matter more: students as maker, learn to do stuff by doing or making the thing.
- Allow it to go.
- There is openness.
- The design is iterative.
- There is ownership.

- Aesthetics matter.

According to Dougherty [26], the term maker is ubiquitous, and the kernel of the human individuality explains about a human being. So, Dougherty [26] interpret the word maker movement concerning people who are related to making rather than where and how the making occurs. According to Martinez and Stager [27], maker movement uses constructive learning theory and, emphasis on the problem solving and physical and digital invention. Educational approaches such as project-based science and problem-based learning focus on learning based on making [28]. In conclusion, the maker movement is a powerful approach to increase the enthusiasm of students in learning complex topics.

#### **2.1.4. Gamification**

Gamification is a powerful tool to improve the motivation and engagement of students in learning. According to Kapp [29], a gamification is an approach that uses game-based mechanics aesthetics, and game thinking to engage and motivate the learner to promote learning and problem-solving. According to Zichermann [30], the ability to learn is incremented by approximately 40% by using the game mechanics or gamification. The commitment and motivation of learners are increased using game-based approaches. Gamification changes the mode and value of playing games to various experiences such as: buying something online, visiting websites or learning.

According to Werbach and hunter [31], there are three different types of gamification:

1. Internal gamification: The internal gamification is used to the trained employee.
2. External gamification: The external gamification target the customers.

3. Behavior change gamification: The behavior change gamification aims toward educational or learning purpose.

The main problem in today's education system is lack of motivation or interest of the student in learning. The teachers try to use new methods and techniques to motivate and engage students in learning. In recent years, many researchers suggest that gamification is one of the possible solutions to motivate and actively engage students in learning. Gamification can be applied to connect pleasure with learning. According to the new Horizon report 2013, games stimulate inquiry and productivity among learners. New Media consortium 2013 horizon reports that Gamification or game-like simulation helps the students to think creatively to solve problems.

Gamification can also be used in the context of online courses. There are many tools available for gamification. Some of the gamification tools are provided by the web, so no installation needed. Some of the most popular gamification tools are: (1) So creative (2) kahoot (3) Flip Quiz (4) Doo Lingo (5) class Dogo (6) Goal book. The most critical value provided by gamification is the enjoyable and voluntary engagement of students in the learning process.

#### **2.1.5. Game-based module**

Ever since the first game came into existence, we have observed a dramatic increase in the popularity of computer games. In the recent years, many researchers see a considerable increase in interest in the subject, when the game was added as a flavor for computer science students [32]. There are already many studies about the use of games for education, and most of them agree that software games provide a tangible, understandable, and appealing context in learning of computer science [33]. It is clear that when anyone is actively engaged in learning, then it is beneficial for learning. In game-based learning, students are actively involved in learning. A commitment to the learning environment facilitates exploration in the subject while engagement

promotes the need to explore further [8].

CS1 and CS2, as defined by Leutenegger et al. [33], are the center of attention for most of the educational research in this field. The problem is intensified when CS1 and CS2 are offered to non-computer science major students. There is also a considerable problem about female students that they are not fascinated with computer science. Existing research and studies have shown the game development theory has been successful for CS1 courses, but there is relatively very few research, which concentrates on CS2. CS2 is still a gridlock for computer science learning. The game based approaches always produce favorable outcomes. There has already been a lot of research paper written over the past few years, which include topics like challenges in computer science education, and various approaches to improving it [34].

There is a great deal of hidden conflict in the didactic technique of computer science. It also suffers from a high rate of dropping enrollment and poor gender diversity [34,35]. Introduction of media and image processing, introduce more comfort and interest in computer science. Some researchers argue that by using media and image processing the students feel more imaginative and some other research indicates that, media is a realm where people have more pleasant communication [36,37]. Games provide an opportunity to learn computer science with more enthusiasm and interest. As the introduction of games in educational experiments provides a remarkable result, game-inexperienced teachers need assistance with introductory games in their lecture [38].

In the recent years, the game approach has been used as a didactic tool for learning of computer science. Now, not only everyone plays or relates to playing games but also many techniques have been developed to create various kinds of computer games [39]. In the game,

based course, students are highly interested, motivated and enthusiastic about the subject.

#### **2.1.6. Gaming module using augmented reality**

In a virtual reality environment, there is a great experience of learning but in this environment, there is lack of natural motor feedback as the learner is not directly interacted with the objects in the real world. The augmented reality-based system can allow sufficient multimodal learning experience by permitting the learners to manipulate the real object in physical space. Managing the object can help the students to more engagement with the course content as it gives an extra mode of learning.

One additional benefit of augmented reality is an increase in the approachability of educational content. Learners can access educational content using computing devices such as desktop, laptop or kiosk when they use virtual reality system for their education, but the student can obtain educational material using portable devices such as a tablet, smartphone or mobile when they use augmented reality system for their education. Augmented reality permits the students to connect with the virtual environment by only pointing the camera in required physical space. The system also promises to attract learners in acquiring new concept using the diversity of various perspective of augmented reality system.

According to Levine, et al. [40], the very first system for augmented reality and virtual reality was used in 1960. According to Milgram, et al. [41], augmented reality based on a "Reality-virtuality continuum" between the virtual environment and the real world. Fig. 1 shows that the augmented reality is a kind of mixed reality.

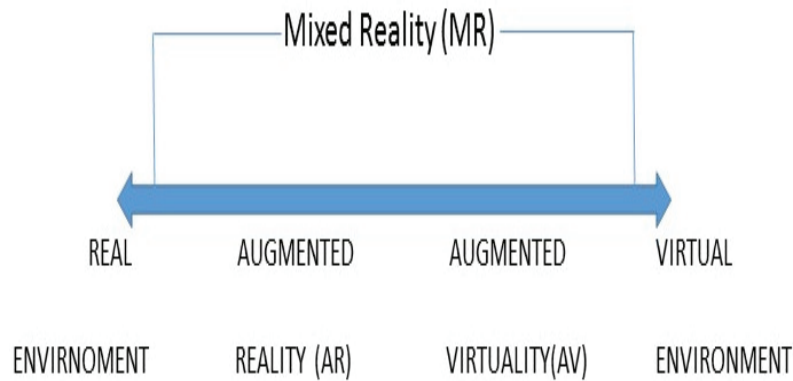


Fig. 1. Milgram et al. 's (1994) Reality-virtuality continuum [41]

According to Chang and Medicherla [42], 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 augmented reality system in education and training is believed to have more inspire learners. According to Kerawalla, et al. [43], the augmented reality system was developed in the 1960's, but its pragmatic employment in education and training started in recent years. Kerawalla emphasizes that, when we use the augmented reality in education, the learner is more motivated and engaged in inventing the resources and applying them in the real world [43].

According to Morreale, et al. [42], there is an augmented reality application known as 'construct3D'. Construct3D was designed to teach mathematics and geometry. This application uses a three-dimensional geometric constructional model [44,45] and permits multiple users to share the virtual space. The users can construct geometrical shape by wearing the head mounted display. It also enables the learners to inlay the computer-generated virtual object in the real world. The users can work with construct3D, and they can get the experience of inscribing a sphere into a cone virtually [44].



Johnson [46], states that augmented reality has the great potential to provide a robust circumstantial learning experience and augmented reality system helps to explore the connection information in the real world. According to Billinghurst, et al. [47], many researchers have indicated that students can enhance their knowledge and upgrade their motivation in learning with virtual reality and augmented reality. The usage of augmented reality begins when Billinghurst [47] created the magic book.

According to Shelton [48], augmented reality is not adopted into school because there is minimal financial support from authority for such experiences and the classroom requires to have more space for students to make use of this technology. Educators can apply augmented reality in astronomy class for the sake of students understanding and enhancing the motivation of students to learn astronomy. Instructors can use three-dimensional rendered earth and sun shapes in the astronomy classroom. According to Shelton [48], the virtual object such as sun and earth are manipulated on a hand-held platform. The students can view the change in orientation and also control the angle of view. So, the students can understand, how the unseen element work with the elements which are previously seen.

In the last two decades, augmented reality has been applied to the educational institution and business industries, but it does not replace the classic or traditional method. Furthermore, the technologies which are used with augmented reality concepts are much more potent than it was before, so it makes the use of augmented reality in education more feasible. Additionally, the wireless device such as a smartphone, tablet, or other electronic inventions has made the use of augmented reality in education more practical and promising.

## **2.2. Learning Environments**

Over the years, the learning environment has significantly changed. An alternative to the traditional environment has been proposed by many researchers. The newer learning environment based on simulation, cooperative, exploratory and constructivism, already superseded the traditional learning environment. Additionally, instructors are frequently looking for more effective methods of learning [ 49]. By convention, learning is defined as, change in conduct or accomplishment from practice and experience. However, learning is more about reconstructing knowledge and understanding rather than a change in behavior. Nowadays, we consider learning is related to problem-solving rather than memorization.

Forty years ago, the learners were requested to complete schooling and then begin a profession or career that is good for their entire life. There is a rapid decrease in the life of knowledge. Before, the life of knowledge was calculated in a decade. Now the knowledge is changing significantly today, the life of knowledge is calculated in month and years. According to Driscoll [50], learning is defined as a remarkable change in human behavior or performance from the experience and the learner's interaction with the world. This definition includes various characteristics of behaviorism, cognitivism, and constructivism.

### **2.2.1. Powerful learning environment**

In a powerful learning environment, affluent contexts and reliable work are introduced to students. In recent years, plenty of work is done for the development of a powerful learning environment (PLE). There are several attempts has been done by the instructors to create an optimal learning environment for the pupils. For developing such learning environment instructors used principle from cognitive psychology and constructivism. Students are not involved in the design of powerful learning environment (PLE). According to Elen and Lowyck

[51], pupils do not feel the learning environment in the same way it was deliberated by the designers.

According to Bransford, Duffy, et al., [52,53], the learning environment should represent the possible use of knowledge in which the students are supposed to be expert, so that the acquired knowledge does not become still. Affluent contexts and tasks which are reliable are given by presenting a link outside of the school. According to Collins, Hannafin, Jonassen, et al. [54,55], there is a need of open-ended learning environment rather than the learning environment emphasis on merely spreading of information. To conclude, the powerful learning environment is a learning environment which includes instructional elements that arouse learners to construct the knowledge actively.

### **2.2.2. Cooperative learning**

Cooperative learning is one of the most extensive and high yielding areas of research and training in education. According to Johnson and Johnson [56,57], cooperative learning exists when the students work together to achieve a shared learning goal. Deutsch [58] states that any student can attain his goal only if all the other group member attains their goal. In the last three decades, cooperative learning is popular in the education system. Cooperative learning is also known as "small group learning." Sometimes the members of the group are assigned a specific job, and sometimes all the members work together without the specification of role or assignment.

According to Johnson and Johnson [56,57], for successful cooperative learning, there are five basic elements.

1. Positive interconnection: pupils are answerable for the group effort.

2. Face to face interaction: pupils supposed to assist each other and they should discuss with eye contact.
3. Individual and group liability: students are responsible for their work and group is responsible for achieving the goal.
4. Group conduct: students need social and collaborative skills to work with each other.
5. Group processing: all the members of the group examine themselves and the group capability to work simultaneously.

The extensive uses of cooperative learning depend on multiple factors. One of the most critical factors is that the cooperative learning is based on several theories in sociology, anthropology, political science, economics and psychology [59]. The roots of cooperative learning are used in social interdependence, cognitive development and behavioral learning theories [60].

### **2.2.3. Constructivist learning**

Constructivism refers to the belief that the learners construct knowledge for themselves. Constructivists focus more on an understanding of knowledge through experience and less on the verifying the concept. The learners are the devoted creator of their knowledge based on the previous idea and new experience. Constructivists believe that the learners are not an empty container to be filled with loads of knowledge; instead, they can make the meaning of the knowledge. The consequence of the theory is twofold.

1. Learners in thinking about learning
2. Learners do not have knowledge which is not related to their experience.

The constructivist theory appears in response to behaviorism and cognitivism. Researchers

believe that a human is not a robot so, he could not be programmed. Constructivists assert that human brain plays an active role in learning. In other words, the learners are much more actively involved than teachers or peers to learn or understand a specific concept. Constructivism refers to both learning theory and epistemology [61]. Regarding learning theory, the constructivists suggest that learners construct meaning and in epistemology, constructivists suggest that knowledge is constructed through discussion or interaction with the peers.

In constructivism, students construct and reconstruct the concept with an attempt to match with the experience. The new concept is matched with student's prior knowledge, pre-conception, and misconception. If the new material is consistent, then it is considered to be learned, and if it is contradictory, then it is considered as "it cannot be learned." Biggs and Tang [62], describes the principle of constructive alignment. As shown in fig. 2, per the constructive alignment, the assessment tasks and the learning activities are directly related to the learning outcomes of the students.

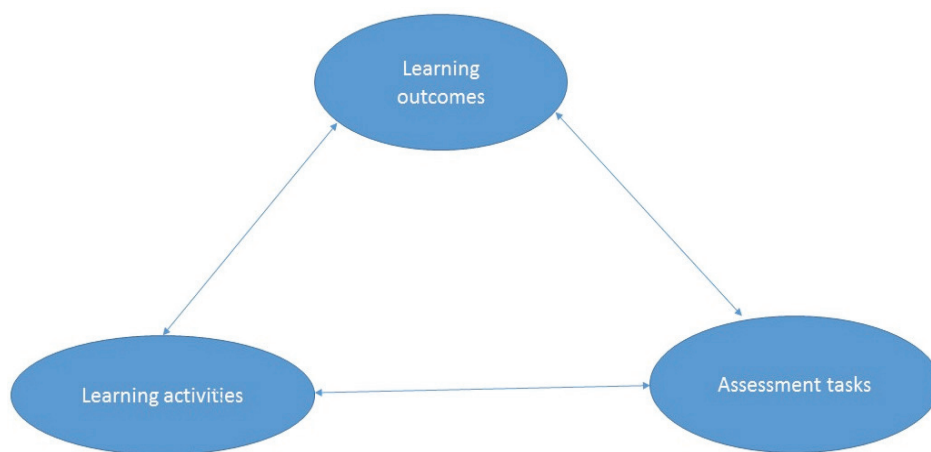


Fig. 2. Constructive alignment (Biggs and Tang, 2007) [62]

#### **2.2.4. Immersive learning**

An immersive environment offers students to immersed in a virtual environment and feeling as if it is real. The immersive environment can allow students affluent and complicated context-based learning. Immersive learning helps the student to sharpen their inventive, imaginative and innovative skill. According to Rist [63], reality and real-world execution are inadequately used to represent the views in the traditional classroom.

Fortunately, from over the last decades' many attempts have been made to improve learning. Many instructors started to use technology such as video and computers, to create a learning environment and to provide the better learning experience to the students. The immersive learning environment can provide engaging learning. Immersive learning permits new framework and quick revision. This kind of learning environment adapts to the individual student needs. Immersive learning collects all molecular data on the accomplishment of individual students or group.

#### **2.2.5. Exploratory learning**

Exploratory learning is an approach to learning or teaching that motivates learners to analyze and explore new concept using the existing background knowledge. In exploratory learning, learners discover the relationship between the existing concept and new material. This approach to learning modifies the traditional structure of both teacher and students completely. In exploratory learning, the learners are offered an open learning environment where the students explore by themselves the principle of the learning material, procedure and other skills related to learning material [64].

According to Melanie and Jong [64], exploratory learning is considered important because of

two reasons:

1. the exploratory learning will motivate meaningful fusion of new concepts in learner's cognitive structure, so it is assumed that the new concept can be learned in a more profound and better way.
2. Comprehension of the exploratory process itself is considered as significant skill.

In recent years, after the introduction of computer simulations, the exploratory learning got more attention. According to Swanson, Veenman, et al., [65], the studies on exploratory learning using computer simulation do not produce an uncomplicated successful result. There is two probable reason for the failure of computer simulations (exploratory learning) as an instructional device. One of the reason is that the exploratory learning is considered too hard for students and students show ineffectual and incapable behavior when they make mistakes. The other considerable reason is that; the students are not as diligent as it was assumed and they have some exploratory skill that they are not using.

### **2.2.5. Simulation-based learning**

Simulation is a technique of training that tries to make a real experience in the supervised environment. In recent years, various knowledge area has used simulation for training and research. Simulation-based learning is a learning approach in which the learners get an experience of the simplified simulated system. In other words, simulation-based learning is a technique that helps students to obtain a real experience of the concepts which they are going to learn. For example, in medicine, the simulation-based training is beneficial. In the military, a simulated model of war game is used to train soldiers or troops to fight under the stress and life-threatening conditions. In human resources, a simulation of official human interaction is used to

access managerial capability and identify management ability. Simulation-based training is also used in traffic management.

Simulation-based learning is mostly immersive, and the learners are provided an excellent opportunity to interact in the simulated environment. Koparan and Yılmaz [66] examined the effect of simulation-based learning on the future teacher's reasoning skill in teaching probability. This study shows that simulation-based probability teaching help to increase the inference skills of the future teachers and this approach of learning influence the success of the students. Many researchers suggest that the simulation-based learning is an experiential effective and fun [67,68]. According to various studies [67,69], simulation technique improves the learning effect and clinical training. Simulation-based learning is mainly used to educate adult professional. Adult learners have diverse experience and backgrounds. They are more mature and self-directed. So, using the traditional method of teaching to teach an adult is a big challenge. As the adult learner want to learn the concepts which have meaning in their life and they want to apply the concepts immediately after they have learned the concepts. Using simulation-based learning adult can learn efficiently, as they are actively engaged in the process of learning. So, they have the opportunity to participate and experience the training or the concept they want to learn. For example, simulation-based learning is used for training in nursing, military, and medicine.

In the earlier method of medical education, the simulator is used to represent the biological process and clinical expression. Nowadays simulator of human patients is used, which provides a real appearance of human patients to the students. Additionally, using virtual reality and multimedia concepts the medical students can interact with the patient and make the medical diagnosis. It also permits students to feel some feature which is used for their study such as the sound of heart and breath, touch experience of the rectal and pelvic exam and, the experience of



virtual surgery.

### **2.2.6. Independent learning**

The concept of independent learning is often associated with other approaches to learning such as "student-centered learning," "personalized learning" and "ownership of learning." According to Candy [70], independent study is a method of education in which pupils obtain knowledge through their endeavor, and also they grow the ability for judgmental assessment of the new concept. The independent study increased the responsibility of students to learn a new concept and acquire various objective and goal. Ability to work independently is one of the key aspects of learning. Many people argue about learning such that: learning is nothing but the discovery of the solutions to a problem. Independent learning requires exploration of new concepts and methods by students. A culture of "spoon-fed academics" in which students are supposed to learn everything in the class has now changed. According to E.M.Forster, spoon feeding will teach nothing in future other than the shape of the spoon. In recent years, many researchers [70,71], suggest that independent learning is more acceptable than traditional spoon feeding methods. In independent learning, there is also the vital role of teachers along with the student involvement.

Successful independent learning relies on various factors such as external and internal factors. The external factor of independent learning consists of a teacher and student relationship. The external factors also include the establishment of an enabling environment. The internal factors of independent learning include (1) problem-solving skills, (2) cognitions skills, (3) metacognitive skills and, (4) the skills which are related to emotions or feeling [72].

The benefit of independent learning:

- There is an increment in the confidence of students and motivation to learn.
- The academic performance is improved.
- The pupils are more aware of their limitation, and they are now able to manage them.
- The independent learning method enables the teachers or instructors to provide a distinguished task to students.

### **2.2.7. Experiential learning**

Experiential learning is one of the most widely known and frequently cited learning theory. For over 35 years, the Experiential learning theory has been used in management learning research. Kunth Lewin and John Dewey made the foundation of experiential learning theory [73]. Experiential learning theory provides a dynamic theory rooted in a learning cycle. Experiential learning theory obtains an essential role in the formulation of the modification of Bulgarian education. In 1984, there was a publication on experiential learning which was hugely successful [74]. Since then, the experiential learning becomes more popular with teachers, trainees, and students who are older than sixteen years. Kolb [74] provide a solid theoretical base for experiential learning. According to Kolb [74], learning is a method to understand a concept using experience.

There are four phases of study in the experiential learning theory. Theses phases relate to (1) doing, (2) observing, (3) thinking and, (4) planning [74, 75]. The nature of the experiential activity is difficult to define. According to Chapman, et al. [76], only participating in the learning experience does not make an experiential activity. The experiential process is more complex and not followed any pre-defined patterns. The nature of experiential learning can be defined using the learning models such as (1) Lewin, (2) Dewcy and (3) Piaget. According to

Lewis and Williams [77], experiential learning is a learning by doing or learning by experience. Lewis and Williams mention that in experiential learning strategy the learners immerse inexperience and then they reflect about the experience for the sake of developing their skills and the way of thinking. The concept of experiential learning based on the fundamentals of constructivist and interdisciplinary learning. In experiential learning the subject we want to learn could be connected to another subject, it is not walled into its room. The traditional method of teaching does not reflect the real world, but experiential learning which is based on a learning experience mimics the real world of learning. According to Wurdinger [78], experiential learning comes together in alliance with constructivist learning. He also mentioned that the learning outcomes of experiential learning are unpredictable and the learners play an essential role in acquiring knowledge. The learners choose the method to solve a problem based on their own experience.

### **2.2.8. Collaborative learning**

Collaborative learning is a method of teaching that includes: (1) a group of pupil work simultaneously to solve a problem, (2) to do a project and, (3) to finish a job. In collaborative learning, students work in a group where the members of the group have different performance level. In modern society, collaboration or working together in a group has become a trend. According to Austin and Welch [79, 80], there is an increase in the need to work in a group and think together to achieve a common goal. According to Leonard and Leonard [81], in modern society, there is more stress on group work rather than working individually, and people prefer community over individuality. Collaborative learning is a teaching approach in which a group of learners works together to achieve a common goal. In collaborative learning, the students do not depend merely on the text or expert's framework. Students can exchange their ideas with their

peers. Students need to adjust socially and emotionally in the collaborative learning environment, and they also require to express and justify their ideas. According to Srinivas [82], in a collaborative environment the students can exchange their ideas, communicate with peers to clear the ambiguous concepts, express and justify their ideas, questions the various framework and are actively involved.

In collaborative learning, there is a remarkable shift from the traditional lecture-based classroom. In the collaborative classroom, the teaching is based on the student discussion and active engagement with the study material. According to Smith et al. [83], teachers who use the collaborative method of teaching, think of themselves as the lead learner rather than as an expert provider of knowledge to the pupils. Collaborative learning is only possible if the group of learners helps each other to learn the concepts. There are a few misunderstanding about the term collaborative learning. Collaborative learning does not mean for the students to talk to each other while they were doing their assignment. According to Klemm [84], if one of the members of the group does all the work, and other members of the group only append their name in the group assignment, then it is not considered as collaborative learning.

According to Johnson and Johnson [85], there are five key components for the successful collaboration in the classroom.

- The first key component is that the interdependence should be positive. The members of the group are ready to provide help and accept help from other group members.
- The second key component is that the account must be individual. Each member learns the course material.
- The third key component is that there should be informative interaction.

- The fourth key component is that the members of the group should know the social skill such as leadership and communications.
- The fifth key component is group processing. It depends on how the members of the group work together.

The selection of group members for a particular group is crucial in collaborative learning. Members of the group can be selected randomly, self-selection or criterion-based selection. According to Rau and Heyl [86], the group having fewer members have less diversity and may not have varied thinking and expertise. So, the group having fewer members is not able to produce the best output. The collaborative learning comprises of two steps which include:

- (1) The first step of collaborative learning is to explain the goal to all students clearly.
- (2) The second step is to specify the collaborative learning structure to all students.

Then the students can present and defend their idea to complete the task and achieve the goal. Students are required to listen to the ideas of other students of the group carefully. Each group member gets the opportunity to articulate and justify their ideas. In the end, the group will reach to achieve the common goal and complete the task.

### **2.2.9. Learner-centered design**

The learner-centered design is a fuzzy notion of learning. In learner-centered design, the need of learner is considered first, and then it involves the learners in the design process. In the interactive learning environment, learner-centered design plays an important role. The need of pupil is the focus of interest when we try to implement a learning system that supports an affluent form of learning. Soloway et al. [87] emphasize the design product such as the

educational software. Few other researchers give priority to the design process and try to integrate student need in that process [87,88]. According to Soloway, et al. [87], the computer system should be designed per the user perspective, and the learning environment should focus on the learners.

In the learner-centered design, there are four key elements to be addressed, which includes:

1. Context: The context is the most crucial element of learner-centered design that includes: (1) The goal, (2) purpose, and (3) audience.
2. Interface: The interface is the front end of the software with which students can interact.
3. Tasks: This includes all the task the learners can do with the software.
4. Tools: The tools support the tasks that students will do for learning.

In user-centered design approach, there is need of three concepts: task, tool, and interfaces. In learner-centered design, the learning model requires four concepts including the three concepts needed for the user-centered design. The fourth concept which is needed for learner-centered design is learners need. According to Conlon and Pain [89], the learning methodology they propose is a combination of user-centered design and action research.

In conclusion, the learner-center design should follow these basic principles:

- The learner-center design should focus on the result in the learner's understanding
- The learner-center design should create and improve the motivation of learners to learn.

- The learner-center design should offer a diversity of learning techniques.
- The learner-center design should encourage the individual's growth using an adaptable software or tool.

### **2.3. The evaluation method of educational games**

Educational software games aim to develop students as a successful learner. However, the computer games are not included in the course curriculum of school until they are evaluated usefully for the majority of students. Freitas and Oliver [90] propose a method to evaluate the learning based on games and simulation effectively. According to Maria and George [91], the educational games can be included in the school classroom only if it is usable and likable by all students. They did evaluation experiments on three categories of students concerning their experience of the game: expert, intermediate and novice player.

The attempt to add educational games in the 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 of the effectiveness of educational games. Another main reason is that still there are criticisms about the usability and likability of existing educational games. For example, according to Brody [92], the marriage of education and game-like entertainment are neither educational nor entertaining.

#### **2.3.1. Likeability**

Fabricatore, et al. [93], 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 [94], disclose that there is a notable difference between the boys and girls in the 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 to the 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 the classroom.

According to Griffith and Hunt [95], approximately one-third of pubescent likes to play software games daily but the almost the same proportion of adolescents play software games only once a month or less. This shows that there is the difference in the extent of proficiency among the students of the same age. Students who play software games regularly have the critical capability of game playing, but the other students have not.

There are two main reasons why students do not play the game:

- Students have not had the chance to play software games frequently.
- Students do not like software games.

Usability can also affect the likeability of software games. If the software game is not usable, then it may be less likable. 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. Virvou and George have stated that likability is proportional to the worldliness of virtual reality-based environment of the game [91]. Interactive and immersive educational games are attractive or likable. However, if the educational games are designed to be more attractive, then it might lose the educational content. There are a few more issues to consider when evaluating the likability of educational software games. One of the notable aspects is that educational software games struggle to captivate an audience that has been exposed to the commercial games that have no educational content. The educational games should not be solely entertaining or solely educational, and it should be a right balance of both.



The comparison between the educational games and the commercial games is inevitable. The likeability of the educational game is dependent on the comparative attractiveness of these games. If the educational games are less attractive than the commercial games, then likability of educational games can be questioned. One of the relevant examples is given by Brody [92], where he mentions that combination of education and entertainment in software games has produced some not very educational games and some not very entertaining educational activities. Attractive educational games will ensure a more significant benefit as the students can play the game in school classroom as well as in their leisure. Playing these games will also bring them closer to their educational goals. Therefore, we need to evaluate an educational game regarding likability.

In 1967, Fishbein introduced a new terminology Theory of Reasoned Action (TRA). In 1975 Fishbein and Ajzen [96] 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 [97]. Shih and Fang [98], 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 [99], there is a relationship between the acceptance of information technology by a hotel employee and their IT-belief, attitude, subjective norm, and behavioral intention. Many researchers have used TRA for determining the relationship between the attitude of the audience and familiarity with the product or technology [98, 100]. Teo and Van [101] 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 worry about the attitude, intention and subjective norm toward the specific behavior. Nguyen and Choudhury [102] 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 [103] 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. The TRA model suggested that the belief will affect the attitude towards the intention or behavior (likability) towards the product or technology.

### **2.3.2. Usability**

The evaluation of educational games considers the usability of educational games. Usability is one of the critical issues that need to be analyzed for the evaluation of educational games. In recent years, various researches have been done on the usability of games which are targeted at children [104,105]. In the opinion of Yacci, et al. [106], the usability of software is significant to analyze whether the effort done by learners to understand gaming interface is gainful or not. They point to the usability of the software, and they ask that it is critical to analyze whether the effort done by students to understand the game is gainful or not. The JIGSAW model [107] or the set of learning with software heuristics, addresses the problem of integrating usability in the evaluation of educational games. In JIGSAW model, the evaluation was done on three levels. In level 1, the learning and operational task consider independent of each other. In level 2, there is integration within learning and operational task. At level 3, there is an integration between the learning and operational task. We, therefore, focused on the fact that software tools are enjoyable enough to wear and use. Besides, usability characteristics of the software tools meet the end-user (student) requirements.

Usability of 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 [108,109]. Several researchers have developed questionnaires for the evaluation of user engagement. Jacques's survey [110] 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 [111] 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 [112, 113] 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 [114,115]. The user engagement scale has six dimensions which include:

1. focused attention (FA)
2. felt involvement (FI)
3. novelty (NO)
4. durability(EN)

5. aesthetics (AE)
6. perceived usability (PUS)

According to Brien [116,117], 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.

### **2.3.3. Motivation and enthusiasm**

Recent studies show that the idea which states that," there is no relation between emotion and learning," becomes obsolete [118,119]. According to Damasio [118], emotions not only determine the intelligence but also we require emotions as a means to intelligent. According to Goleman [119], if the students are angry, uneasy or distressed, then they do not learn efficiently. So, for better learning outcomes it is necessary to evaluate the motivation and enthusiasm of the learners. Using self-report approach we can evaluate the motivation and enthusiasm of students for a teaching approach. Del Soldato [120] introduced a motivational modeler and a motivational planner to measure the level of motivation when students used traditional intelligent tutoring system for learning new concepts.

According to De Vincente & Pain, [121], motivation is an essential aspect of the educational software, and the motivation is analyzed by using a method named motivational diagnosis. Matsubara and Nagamachi [122], state about instructional planning to increase motivation. The likeability is considered as a factor of motivation. We need to evaluate if an educational game is motivating or not. According to Keller [123], it is not always possible that if the instruction is of good quality, then it will motivate the students. Many researches deal with motivation [120,121]. Angel de Vincente and Helen Pain presented an empirical study, which

showed a significant amount of knowledge related to motivational diagnosis [121].

In AI and educational research, the pupil's motivation is virtually unexplored. In the traditional method of teaching teachers or instructors get cues from the students through a mixed communication medium such as posture and, facial expression. However, many of these cues are unrelated which makes it difficult to evaluate the motivation of students. Angel de Vicente and Helen Pain designed a study in which an instructor is asked to conclude pupils motivational state. For this study, they used prerecording of students' interaction with the system. The researchers concluded that the evaluation of motivation would be easier if they use the video recording of the students' interaction [121]. The duration of time the students spend with the software is also noteworthy.

#### **2.3.4. Immersive vs. non-immersive**

The objective of virtual reality-based games is to provide the users with 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 a head mounted display, data gloves, and oculus rift. The virtual reality hardware provides the users a full virtual immersion as well as six degrees of freedom. The other form of virtual reality game is non-immersive. The non-immersive games also provide the users with a virtual 3-D environment that can be directly manipulated. The students will engage more in their study when the immersion of the game is increased. Many researchers have shown on the positive experience of users, with the various level of immersion [124] According to Roy A. Ruddle [125], if we compare the movement of player in the virtual environment using HMD (immersive) and desktop computer (non-immersive) then, the player using HMD was 12% faster than the users who didn't use HMD. 'NICE' is an excellent example given by Roussou M.

[126]. NICE is an immersive virtual reality-based game which provides students an immersive virtual environment and students learn the basic biological concept by creating and cultivating a virtual garden. Another noticeable example is VREAL provided by Edge R. [127]. VREL (virtual reality education for assisted living) is the only virtual reality environment for deaf and hearing disabled students, which is funded by the United States department of education. VREL provides an immersive virtual environment in which the hearing deficient students can learn the language, art, and basic mathematics. Adamo Villani and Arns L. [128], provide an illustration SMILE, which follows the path introduced in NICE [126], and VREL [127]. SMILE has an immersive virtual environment which provides users to interact with the environment in both spoken and written English. The goal of SMILE is to make learning fun.

A fish tank based on virtual reality system used for SMILE, consist of fully immersive virtual reality environment. In this system, the user can use essential reality p5 glove with six degrees of freedom for tracking and bending sensor for each finger. While using SMILE user can also use a pair of e dimensional wireless 3D glasses and a three degree of freedom (DOF) PC head tracker.

According to slater and Wilbur [129], immersion is based on the explanation of what any technology contributes or how much the system can offer the inclusive, extensive surrounding and vivid illusion of real-world. According to D.A. Bowman and R.P. Mc Mahan [130], the virtual environment which has a higher level of immersion will produce a great sense of presence. According to Mujber [131], the virtual reality system based on immersion can be classified into three categories:

1. Non-immersive desktop system

2. Semi immersive projection system
3. Fully immersive VR system

Immersive and non-immersive both virtual reality technologies provides an excellent platform for education. According to Pantelidis [132], there are various reasons for the use of VR in learning such as visualization, motivation, interaction, and collaboration.

#### **2.4. Framework for evaluating games and the instructional module for learning**

Several attempts have been made to introduce the framework for evaluating the learning outcomes based on technology. However, the lack of a robust framework has a significant impact on the uptake of educational games in a school classroom. Oliver [133] points out the TILT, CIAO, and Flashlight framework is used in the evaluation of teaching which is integrated with technology. According to Ehrmann [134], the flashlight framework evaluates the relationship between three components: the technology, the activity for which it is used and the learning outcomes. The CIAO framework is more flexible than the flashlight, and it supports the use of interview, observation and documentation analysis along with the surveys. All of these frameworks were introduced to consider technology in general.

Freitas and Oliver [90], proposed a four-dimensional framework which helps tutors evaluate the learning outcomes of students based on the learning with games and simulations. In this framework, practitioners consider four main dimensions before using games in their practice. This four-dimensional framework is considered as an iterative method and shows a method of evaluation that an instructor should consider before the evaluation of games and simulation-based learning tools [90].

##### **2.4.1. Framework for simulation-based learning**

There is a need of useful framework that supports the evaluation of the effectiveness of software tool in the learning context. According to De Freitas [90], due to lack of good framework, there is an impediment to implementing simulation and game-based learning in the school curriculum. Dawes and Dumbleton [135] explore the problem of implementing the educational software games in the classroom. They also explore the need to find the relevance of educational games within the school curriculum. In 2004, De. Freitas and Sara [90] suggested a framework to help the instructor to evaluate the effectiveness of the simulation-based learning. According to them, when the instructor thinks about the introduction of simulation-based learning in the classroom practice, they have few queries.

For example:

- For the learning context, which game or simulation should be selected.
- For better learning outcomes, which pedagogic approach should be used.
- To find the validity of a specific game or simulation.

Several frameworks exist which are concerned with learning and new technology. For example, TILT, CIAO, and flashlight framework [133,134]. However, these frameworks were used for technology in general. According to Woods [136], the use of games in education is a novel idea. De Freitas and Oliver [90], proposed a framework which referenced the activity theory. This framework elaborates on the Kuutti's concept of activity theory [137]. Activity theory was initiated by Russian psychologists in the 1920's and 1930's. Vygotsky formulates the basic concept of activity theory. According to Vygotsky [139], collaborative learning is a process that considers social plane before the internal plane. Vygotsky depicted the human action pictorially as a tripartite structure (figure 3); where the subject is human actor or agent (individual), the object is problem space (objective).



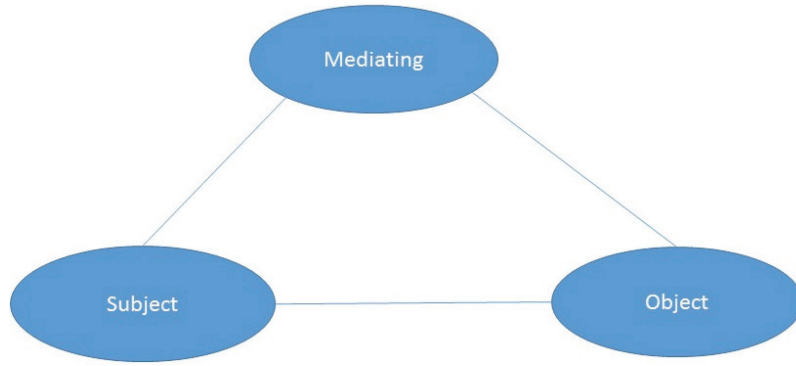


Fig. 3. Basic meditational triangle [138]

As shown in Fig. 4., Vygotsky and his colleagues proposed the basic structure of the individual activity system, where tool mediates between subject and object and in the transformation process from object to output. Subject (human actor) achieves an object (objective) with the help of the tool. The activity is mediated by tools. In activity theory, activity is the key element of development for both subject and object. In other words, activity is the basic unit of analysis.

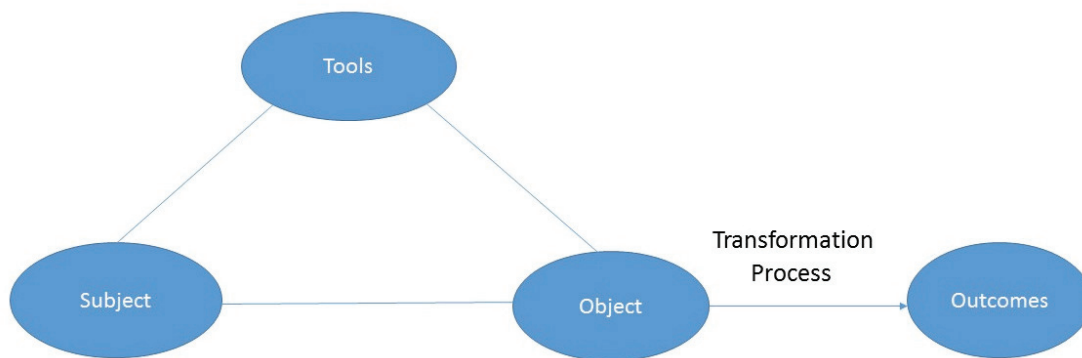


Fig. 4. Basic activity system by Vygotsky [140]

The second generation of the activity system is depicted by Engstrom as shown in figure 5. In 1993, Cole and Engestrom [141] extended the basic meditational triangle (fig. 3) by adding rules, community and division of labor as shown in figure 5. Cole and Engestrom provide a

descriptive tool to analyze students using video games for their education. This is mainly used for studying the motivational activity. The rule is laws, regulations, policies, standards, and practices used in the tools to achieve the object. The community is a group of people who have the same concern as the subject with the problem space (object). The division of labor is between the community member which is aimed at the objective (object) and the rules regarding the action.

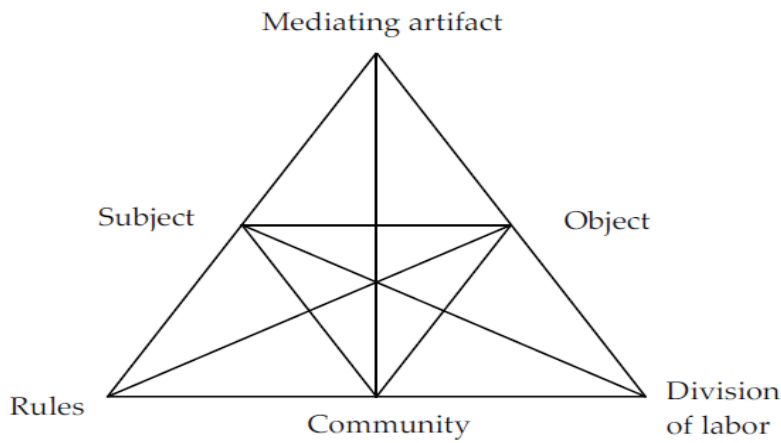


Fig. 5. The extended form of the basic mediational triangle which includes rules, community, and division of labor [141].

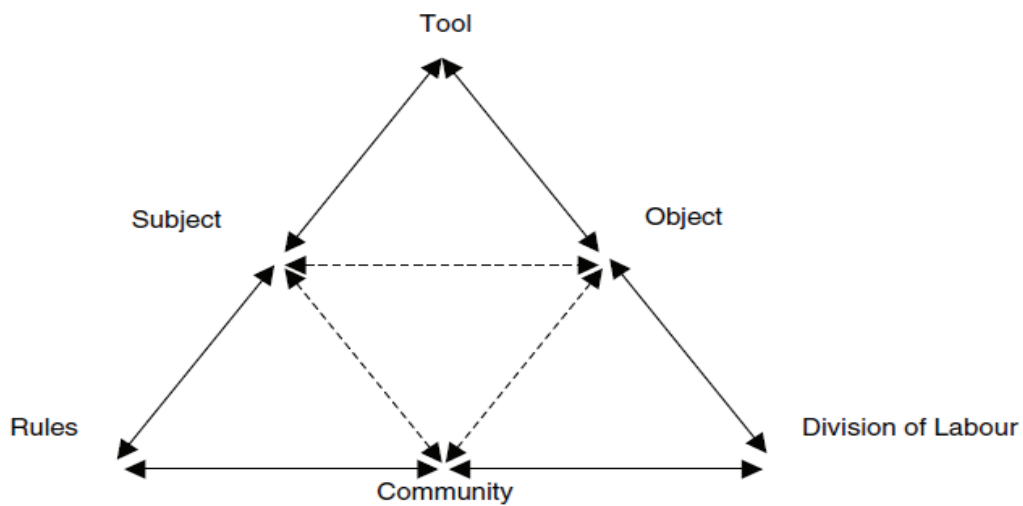


Fig. 6. Triangular activity system [90]

According to Kuutti [137], activity in the form of doing which leads to an object and; various activities are distinguished from each other based on their objects. De Freitas and Oliver referenced activity theory to elaborate the framework. A familiar triangular activity system to represent the framework proposed by De Freitas and Oliver [90] is shown in fig. 6.

Table I. Summary of an activity system

Author:	Description:	Example:
Vygotsky (1896-1984) 1978	The human action as a tripartite structure.	
Vygotsky, A. R. Luria and A. N. Leont'ev 1983	The basic structure of an individual activity system.	
Cole and Engestrom, 1993	Extends the basic mediational triangle by adding rules, community, and division of labor	
Kuutti 1996	Extension of the basic individual activity system, used as the reference by Oliver in his framework.	

De Freitas and Oliver [90], proposed a framework which inherits the primary triad (students, teacher, and tools). There are four dimensions in Oliver's framework to find the effectiveness of educational software tool. These all four dimensions together provide a framework for both existing and future educational games or simulation-based learning. Fig.7. represents the iterative cycle which is used as a framework to evaluate the games or simulation-based learning. In the iterative cycle, a tool is taken as the mode of representation; the subject becomes learner's specification; the object and rules map to approach of teaching and; the community and division of labor become context.

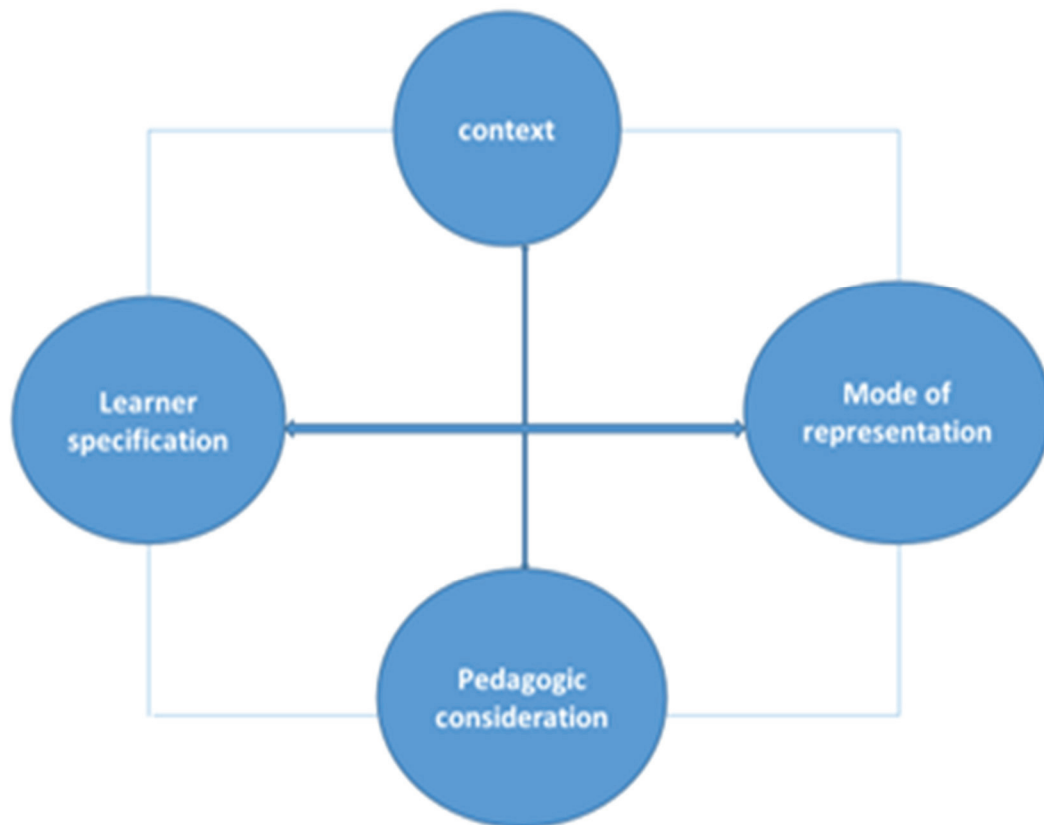


Fig. 7. Framework for finding the effectiveness of simulation-based learning [90].

There are four main dimensions of this framework. These dimensions are considered before using the game or simulation-based learning in the classroom curriculum.

- The first dimension of the framework emphasizes the specific context, where the learning takes place. The context includes classroom-based, outdoors, access to equipment, historical or political factors and technical support.
- The second dimension of the framework emphasizes the attributes of learners. This includes learner's profiles, learning the background of learners and group profile.
- The third dimension of the framework emphasizes the mode of representation which includes the level of fidelity, interactivity with the software tool and level of immersion.
- The fourth dimension of the framework emphasizes the methods of learning both during the traditional classroom curriculum and the simulation-based learning. This dimension of the framework reflects the learning theories, method or approach of learning and learning model to support better learning outcomes.

In 2001, Marc Prensky [142] proposed a table that shows various kind of learning activities and possible game style as shown in the table. II. There are four fields in this table. These fields are considered before using games in the classroom curriculum.

- The first field of the table emphasizes the specific context, the kind of learning. The context includes facts, skill, judgment, behavior, theories, reasoning, process, procedure, creativity, language, system observation, and communication.
- The second field of the table shows the examples of learning. This includes rules, approach, management decision, interviews, exercising self-procession and morality.

- The third field of the table emphasizes learning activities which include queries, drilling, memorization, imitation, response, regular practice, and growing challenges.
- The fourth field of the table shows the possible game style. This includes role-play, flash card, detective, adventures, and mnemonics.

Table II. Approaches to learning [Prensky 142]

Context	Examples	Learning Activities	Possible game style
Reasoning	Strategic and tactical thinking, quality of analysis	Problem Examples	Puzzles
Process	Auditing, strategy creation	System analysis and deconstruction Analysis	Strategy games Adventure games Simulation games
Procedures	Assembly, bank teller legal procedures	Imitation Practice	Timed games Reflex games
Creativity	Invention Product design	Play Memorization	Puzzles Invention games
Language	Acronyms, foreign languages, business or professional jargon	Imitation Continuous practice Immersion	Role-playing games Reflex games Flashcard games
Systems	Healthcare, markets, refineries	Understanding principles Graduated tasks Playing in microworlds	Simulation games
Observation	Moods, morale, inefficiencies, problems	Observing Feedback	Concentration games Adventure games
Communication	Appropriate language, timing, involvement	Imitation Practice	Role-playing games Reflex games

The framework shown in fig.7 can be represented in checklist style as demonstrated in Table III. Using this table relationship between context and game is analyzed. This table is used by the instructor before the games, or simulation-based learning is applied to classroom curricula.

Table III. Framework for evaluating educational games in checklist style

Context	Learner specification	Pedagogic consideration	Mode of representation
What is the context for learning?	Whom is the learner Find the background and learning the history of the learner?	Determine the pedagogic model and approaches?	Determine the software tools or contents to support learning?
Does the context such as technical support, resources, accessibility can affect learning?	Find the learner's style/preferences? Who is the learner group?	Find the most effective pedagogic model and approaches?	Find the level of interactivity to support learning?
Find the link between context and practice?	How can the students or student group be best supported?	List the curricular objectives? What are the learning outcomes? Determine the learning activities?	Find the level of immersion which is needed to support better learning outcomes?
	Find the ways the group working together? Find the collaborative approaches to support group learning?	How can the learning outcomes and activities be achieved using existing games and simulation? How can the learning outcomes and activities be achieved using the developed software tool?	Determine the level of realism to achieve learning objectives?
		How the briefing/debriefing supports the learning outcomes?	Find the link between the game/simulation and reflection upon learning?

For effective game-based learning, an evaluation framework is required. The purpose of this evaluation framework is to find the main potential evaluation categories. The framework can be used at the time of development as well as during embedding games based learning in curricula.

The frameworks which are based on an activity system is summarized in Table IV. Cole and Engestrom extend the basic activity theory. Kuutti also extends the activity theory and represents mediating artifacts as the tool. De Freitas and Oliver used Kuutti's activity theory concepts as a reference and divided the framework into four dimensions. In their framework, a tool is taken as the mode of representation; the subject becomes learner's specification; the object and rules map to approach of teaching and; the community and division of labor become context. Paraskeva, Mysirlaki, and Papagianni [143] developed a framework to evaluate game-based learning, based on activity theory. In Paraskeva's framework subject is taken as individual learner, small group and, peer learning; tool is taken as devices, chat, databases, internet recourses; the object maps to the learning group, school community, internet community and rules maps to games rules, content rules, internet resources; the community maps to learning group, school community, internet community, and division of labor becomes game roles, teacher and student.

Table IV. Summary of approach

Author	First Category	Second Category	Third Category	Fourth Category
Cole and Engestrom, 1993	Community and division of labor	Subject	Object and rules	Mediating artifacts
Kuutti (1996)	Community and division of labor	Subject	Object and rules	Tool
Prensky, (2001)	Context	Learning Activities	Examples	Possible game style
De Freitas and Oliver (2006)	Context	Learner specification	Pedagogic consideration	Mode of representation
Paraskeva, Mysirlaki, Papagianni (2009)	Learning group, The school community, internet community. Game roles, teacher and student.	Individual learner, small group, peer learning.	Learning group, The school community, internet community. Games rules, content rules, internet resources.	Devises, chat, databases, Internet recourses.



### 2.4.2. Applying the framework

The framework proposed by Freitas and Oliver inherits the primary triad of features which includes student, teacher, and the resources. An iterative cycle is used to represent a systematic approach that evaluates learning tools with best structuring judgments.

#### 1) Context:

- a. What is the context of learning?
- b. Does the context affect learning or not?
- c. What are the links between context and practice?

#### 2) Learner specification:

- a. Who is the learner?
- b. What is the learning style?
- c. How to provide the best support for the learner and learners group?
- d. In what ways, are the groups working together?

#### 3) Pedagogic consideration:

- a. Which pedagogic models and methods are used?
- b. What are the curricula objective?
- c. What are the learning outcomes? What are the learning activities?
- d. How can the learning activities be achieved using existing game and simulation?

- e. How can the learning outcomes be achieved using the specially developed software?

4) Mode of representation:

- a. Which software tools would support the learning activities?
- b. What level of immersion is needed to support learning outcomes?
- c. What level of realism is needed to achieve learning objectives?
- d. What is the link between the game and the learning?

5) Examples application:

- a. Savannah
- b. Media Stage

### **2.4.3. Case studies for evaluation of gaming module or games based learning**

#### Case study1: Mediastage

Mediastage is an educational game like software, which helps the students to experience various aspect of learning in the area of theater, television or film production. Nowadays, mediastage is used to support learning in various media schools. Mediastage is virtual 3D production studio, and it is entirely realistic. Using this software tool student (11-14-year-old) can experience script writing, set building, direct action, lighting, recording and camera skills. The students can manage gesture movement and speech of avatar. They can also experience the voice track and lip synchronized character or avatar. According to Woolley [144], this software tool permits the students to create their virtual environment having unique character and

dialogue.

Many researchers suggest this software tool follows community learning approaches to encourage and empower the learners to create their content [145]. This method also relates to collaborative learning approaches and motivate the students to learn independently. According to Lazarus et al. [145]., the media stage follows a new trend. He also mentions that this tool emerges from community learning approaches. Lazarus et al. explore the development of this software tool which is designed to help the learners to design their context. Another good example which follows this trend is the 'Making game project,' which aims to give the learner with the software tools for developing their virtual interactive environment. This making game project is funded by DIT PACCIT.

A game or simulation needs to be evaluated before introducing in the school curriculum. Freitas and Olives [90], work to evaluate the effectiveness of the software "Media stage." Table V can be used to support the evaluation of Mediastage. This table is based on the four-dimensional framework suggested by Freitas and Oliver [90]. This framework evaluates the pedagogic use of the software tool. Using this framework (Table V), we can select the right content and find the optimal way to implement this software tool within the learning context. From the table V, we can find the components which are needed to integrate to improve the learning outcomes and support the school curriculum.

Table V. Four-dimensional framework for Mediastage

Context	Learner specification	Pedagogic consideration	Mode of representation
In school for media studies.	The learners' age is between 14 to 16 years.	Use of experiential learning which helps learners to learn from abstract thought and conception to concrete action and reflection	There is a medium level of fidelity
It is based on the classroom.	This software tool is used primarily for GCSE level. It can also be used in an informal setting by various aged students.	Learning outcomes: Interaction with film craft and methods allows the learners to experience the process of film and stagecraft.	MediaStage has a high level of interactivity between the media studies and the learners 'experiences. Mediastage allows the student to develop an understanding of the functionality of the tool.
There is the interaction of students with the software.	It can be used by students individually or in a group.	Learning activities: The learners learn through activities which are based on directing a film or play.	Learning activities and outcomes achieved. Supports an increased awareness of the students of the processes of filmmaking and stagecraft through increased handling.
The software tool 'Mediastage' supports GCSE Media Studies curriculum.	The learner with different learning style can use this tool per their preference.	Briefing/debriefing: pre-class preparation and post activity consideration and reflection.	
		Simulation embedded in the lesson plan of the tutor. At different stages of the learning process, individuals will need different levels of attention from the tutor.	

According to De Freitas and Oliver [90], there are few challenges to complete this table. For example, we need emphasis on the pedagogic models and methods, which are required to introduce a software tool into the effective execution of learning. In 1984, Kolb presented the concepts of experiential learning, which can be used in this context [74]. The experiential learning is used to help the cyclic transition from abstract thought and conception to concrete action and reflection. This table can support a reflection of the instructor on the software tool to support the school curriculum. Learners may want to practice using the tool at home in their leisure time. This table can also be used to evaluate the software tools in the home context. So, this table (framework) supports the formal as well as informal learning. One of the remarkable strength of the software tool 'Mediastage' is that the 'Media stage' is designed in pace with the GCSE media stage curriculum objective. The teachers of GCSE media studies wanted to include game and simulation inside the class curriculum.

#### Case study 2: Savannah

Savannah is a mobile gaming strategy, developed by Facer et al. in 2004 [146]. This tool supports children to understand the behavior of the animal. The mobile game 'Savannah' was played by ten children of 11 and 12 years old. The children explored the game to learn a new concept. This game needed a high level of technical support. So, it is considered as an elaborate game by the users having no or less technical support. From last few decades, several researches have been done on the issue of interaction between the virtual and real world [146]. The researchers used virtual reality, augmented reality and mixed reality to analyze various human and computer interaction. According to Facer, et al. [146], many educational researchers start thinking about this kind of software tools that supports experiential learning to promote the students to develop their thinking skill.

Savannah has two related space:

The first one is the outside space (100m X 50m), where the children can play by interacting with the virtual world of Savannah. The children can explore the risk and opportunities of the lion. They can use global positioning system (GPS), which is linked to personal digital assistants (PDA). So, they can 'see,' 'hear' and 'smell' the virtual world savannah while they navigate in the real world.

The second one is the 'Den setting' which is an indoor space, where the children can access various resources for better understanding of the concepts. The children are also able to develop new strategies for living as the lion. In 'Den setting,' there is one flip chart and an interacting whiteboard. In the whiteboard, there is a map of virtual world savannah. There is also a sequence of "energy bars" inside the whiteboard. These energy bars show the relative energy of each lion. When the children reach the den, they can use a whiteboard to recollect the sound and images they confront at the specific location.

The Savannah project was tested on a relatively small number of students, but Facer et al. establish a belief that the mobile game 'savannah' facilitated learning. According to Facer et al. [146], the attempt to add a more conventional "schooled" experience with the interactive virtual reality games was least successful. The reason behind this is that it is very tedious to the made link between the curriculum and the game design. In the classroom students and instructors have unlike context of interaction from the outdoor activities. There was negligence of cross-examine session, so there exists incompatibility between the games and the curriculum of schools.

The students' play pretends games in their school playground and pretends as someone or something. They do not need the interactive virtual world for their pretend game. So, it was very

easy for them to role play as the lion in the interactive virtual environment. They said that they felt very hot and tired as the lion. The table VI suggest the framework used to evaluate the project 'Savannah.'

Table VI. Four-dimensional framework for 'Savannah'.

Context	Learner specification	Pedagogic consideration	Mode of representation.
School based learning.	The learner's age is between 10 to 12 years.	Savannah involves activities and activity based theory. Also, based on experiential learning.	There is a medium level of fidelity
It is classroom based and playground based.	The learner with different learning style can use Savannah per their preference.	Learning outcomes includes: increased empathy with animals, understanding of how animals behave.	High level of interactivity.
There is Engagement with topics from within natural history.	Savannah can be played as part of the pilot project	Learning activities for Savannah is playing as lions, to achieve the learning outcomes	Learning outcomes are partly achieved by empathising with the animals and partly achieved by play activities.
Significant technical support and resources are needed for Savannah.		Briefing/debriefing have been embedded in Savannah.	High level of realism

It is comprehensible that the educational games support learning. We need to find, how to use the educational games efficiently. It is not sufficient that the educational games are used only outside the school. So, the context of the game is needed before the beginning of the design of the game. It is easy to evaluate whether the educational game is beneficial or not using the four-dimensional framework. The four-dimensional framework should be considered before the

design of the game. The educational game designer needs to discover the requirements of the class curriculum and the framework which satisfy the requirements of the curriculum. If the educational game is evaluated using the framework, then there will be more chances of creating significant challenges for students and an opportunity of cross-examination session. The four-dimensional framework ensures better learning outcomes and enhances the opportunities for children to work together.

### Case study 3: VR-ENGAGE

VR-ENGAGE is a virtual reality educational game which is used as a learning tool for better learning outcomes. It is an intelligent tutoring system and consist of four components, namely the user interface, the domain knowledge, the student modeling component, and the tutoring component.

VR-ENGAGE is analogous to a popular game DOOM which has many virtual theme worlds to navigate, and the goal is to reach the exit. VR-ENGAGE also has many virtual worlds to navigate, but the only difference with the DOOM and other virtual game is that it does not have any violent content. Instead of violent contents, the VR-ENGAGE has educational contents or hurdle to achieve the goal of reaching the exit. VR-ENGAGE interacts with students using animated agents. The player finds close doors which are guarded by dragons, while he is navigating through the virtual world. The dragon asks questions about the geography discipline. If the player gives the correct answer, the door is open, and he gets full points for the answer.

VR-ENGAGE is also filled with full of adventure like other commercial games. One of the adventures is that the player may find few objects in virtual worlds and by clicking those objects he will get the hint for future questions. The hint or clue is not for the same part of the virtual



world, but it refers to a question the student might answer in another part of the virtual world. The idea behind this adventure is that the students develop the remembering power. For example, a blue ball is an object which is used as a hint in a virtual volcano world.

Another kind of adventure is that the students are given a key for the closed door after answering ten correct answers. The player can use that key when he does not know the answer to the question posted by dragon on a particular door. In VR-ENGAGE, the students navigate the virtual worlds using a keyboard and mouse. Sometimes a player gets lost in the virtual world, and then they can use a map which is a two-dimensional view of the virtual world. The map is available online to use by the player. The players can locate themselves inside the map and find the tutor hint which is available in the virtual world.

The evaluation of VR-ENGAGE was done to find the effectiveness of the gaming software. In the evaluation, we find whether the VR-ENGAGE motivate the students or the students get distracted in the virtual environment. Maria Virvou [94] experimented to compare VR-ENGAGE with one another educational software with the same educational content. The difference between VR-ENGAGE and the other education software is that the other educational software does not have a gaming approach. The software had a simple user interface than the VR-ENGAGE.

According to Markopoulos and Bekker [147], the students should know the context and purpose of learning for successful use of the technology. Different social context has a different effect on the likability of the students. Thus, the usability and likability were evaluated in both the classroom and home environment. The experiment was done to estimate the usability and likeability of VR-ENGAGE in three ways.

1. VR-ENGAGE individual rise.
2. The comparison of usability and likeability of VR-ENGAGE with the other educational software having no gaming interface.
3. The comparison of VR-ENGAGE with a commercial game.

For the evaluation, fifty students of age 11-12 were selected from five different geography classes. All the students from the five classes were asked about their familiarity with the computer games. Then the students are separated into three groups of a novice, intermediate and experienced player. Later, random students from each group were selected so that there are students from each category for the experiment. There are 15 novices, 20 intermediate and 15 experienced students are selected for the evaluation of the experiment. The novice players were given the training to play virtual reality game before the start of an experiment.

In the first part of the experiment, the students were asked to play VR-ENGAGE for two hours in the classroom. The students were not allowed to take any help from the instructor or other students in the classroom. The data for the evaluation was collected either from the computer-logging or the self-reporting. According to Chou [148], one of the main benefits of computer-logging is that it accumulates data contentiously without interfering with the users. The advantage of self-reporting is that the data is accumulated directly from the users. On another day after the students used VR-ENGAGE, the students were given two hours to work with another educational software. Both the educational software game or non-game have the same educational content. The only difference between them is that VR-ENGAGE has a gaming approach and the other application has no gaming approach. For example, one of the question from geography domain is asked in VR-ENGAGE, and the same question asked in the non-

gaming application.

Then, after spending two hours with each educational software VR-ENGAGE and non-game, the students were asked to choose to use either VR-ENGAGE or non-game software to revise. The students who spent most of the time with VR-ENGAGE are considered to like more VR-ENGAGE over non-gaming software.

In the second part of the experiment, the students were given VR-ENGAGE and another commercial game to take home and play in their leisure time. The logic behind this part of the experiment is that the evaluation was done to find out whether VR-ENGAGE could replace other commercial games which have no educational contents. The commercial game has the larger virtual world, better sound effects, and superior graphic. Students were asked to play the game they like. When the students came back, they were asked a list of questionnaire based on the usability and the likeability of the VR-ENGAGE in comparison to the commercial game. This part was mainly self-reporting as computer logging was not possible in this case.

The data which were collected during the first two hours of the first part of the experiment was used to find out the usability of the software VR-ENGAGE. The analysis of the usability of VR-ENGAGE was based on three main characteristics of the student's interaction of the game.

1. Interface acquaintance
2. Navigational effort
3. Distraction

The virtual reality user interface is a crucial part of virtual reality-based games. Thus, it is essential for students to get familiar with the user interface. The students need to understand the

user interface of the virtual world before playing the game. In VR-ENGAGE, there were few interface concepts such as inventory, map or, the tutor is added, to help students and make their experience joyful. The wasted time is calculated by calculating the number of times user missed the use of inventory, map and tutor hint. The results show that novice user did not use most of the interfaces. Novice users missed use of the interface, a maximum number of times as they are not acquainted with the game and the virtual environment.

When the first hour of the game is compared with the second hour of the game, there was an improvement in the use of interfaces for novice and intermediate students. Thus, the learnability of the game is quite high. One of the significant problems with the game is that inexperienced students face problem in the navigation of the virtual space. The navigational malfunctions were twofold. The users can have aimless movement, or they may have the disability to move.

The likeability of VR-ENGAGE is evaluated by the author in two comparison studies. The first study was about the comparison of the likeability of VR-ENGAGE with the likeability of other non-gaming educational software. The second study was about the comparison of VR-ENGAGE with a non-educational (commercial) game. The likeability is measured concerning how much time students dedicated to each game and evaluated using the data from student's questionnaires based on the likeability of the game in their leisure time at home. After the analysis of observable student behavior, it was concluded from the result that the VR-ENGAGE is more likable by the students. In the analysis of a comparative study of VR-ENGAGE with a commercial game. It was concluded that commercial game was preferred over VR-ENGAGE in the leisure time at home during the weekend.

## CHAPTER 3

### METHODOLOGY AND IMPLEMENTATION

#### 3.1. Introduction

As discussed in chapter 2 (literature review), previous work shows that the game based learning produces better learning outcomes for computer science students. In this research, we have used a proven framework developed by De Freitas and Oliver [90] for the development and evaluation of game theme-based instructional (GTI) modules. We have extended the framework to include: (1) Motivation and engagement in the pedagogic consideration, (2) Usability and likability in pedagogic consideration and, (3) Inclusion of Virtual Instructor in the mode of representation.

We have designed and developed the GTI modules to teach complex topic using gaming metaphor. The complex topic would include multidimensional arrays, linked list, stack, queues and, binary trees. For our work, we have selected two complex topics, namely linked list and binary trees.

We have used the plan-driven software development process for the development of GTI modules because the Plan-driven approach is used when the requirements are stable or fixed. The requirement specifications of GTI modules are known at the start of the research and changes are limited during the design process. Plan-driven methodologies include the functional and non-functional requirement, detailed plans for research design, implementation, testing, evaluation, and maintenance. Our proposed GTI modules are classroom-based and lab-based, but the module can be used outside the class during student's leisure time. We have also utilized the waterfall model to develop the GTI modules.

### 3.2. Waterfall model

In the waterfall model, where one task completes before the next task begins, we have planned the steps of development from the beginning until the project completion. Fig. 8 depicts the implementation of the waterfall model in the development of the GTI modules.

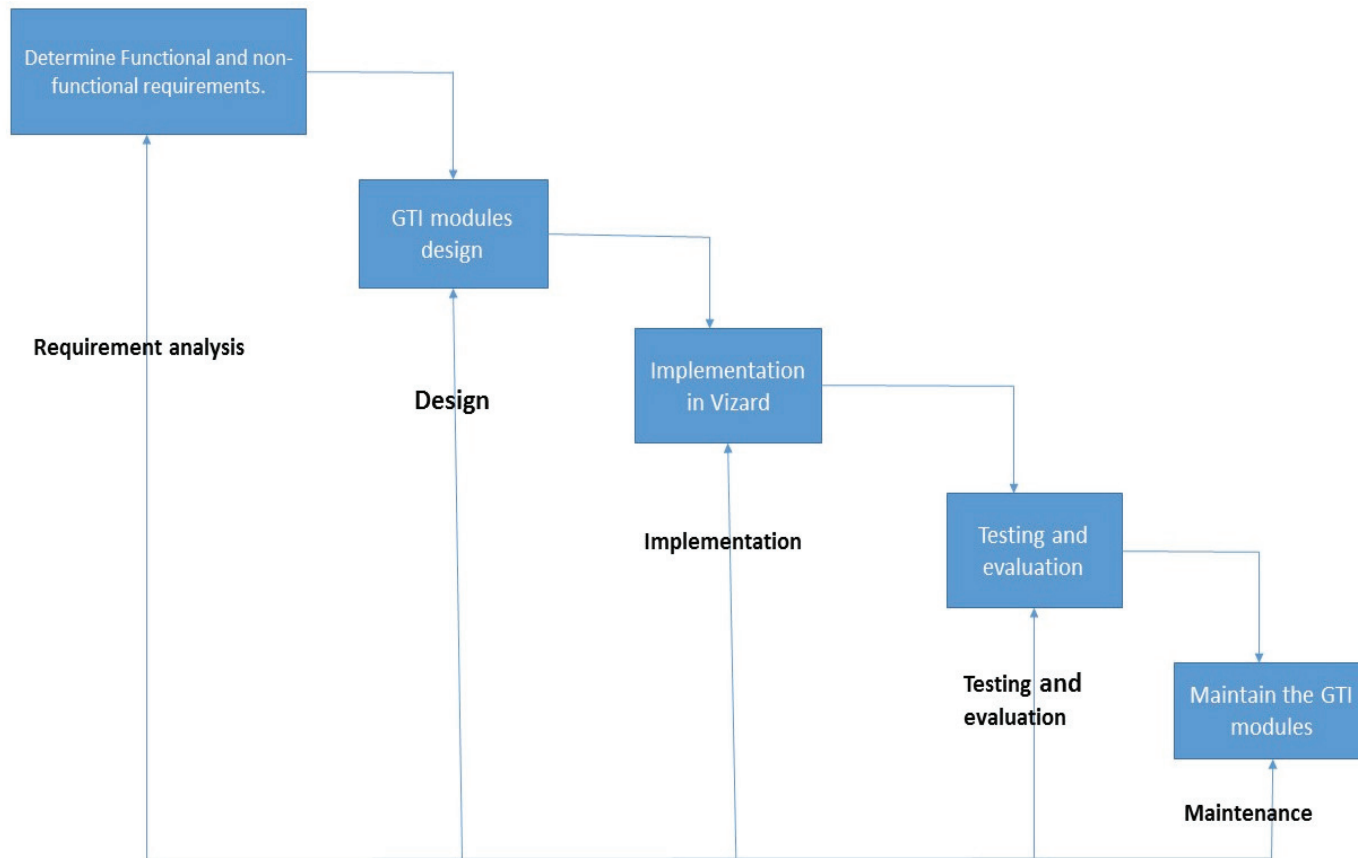


Fig. 8. Waterfall model for the development of GTI modules.

The identified phases in the waterfall model are:

1. Requirement analysis: We identified the functional and non-functional requirement of GTI modules.
2. Research design: We have used FDF (four-dimensional framework) with minor extension to design the GTI modules.

3. Implementation: We have implemented GTI modules using python source code in world-viz Vizard environment.
4. Testing: We have tested the GTI modules with the help of my colleagues in a virtual reality lab, where we assessed the usability and likability of the GTI modules.
5. Evaluation: We have evaluated the completed modules with the help of the undergraduate students. These students were enrolled in introductory programming course of computer science department.
6. Maintenance: We may need to maintain the GTI module and fulfill the loopholes/flaws of the GTI modules.

### **3.2.1. Requirement analysis**

The target audiences of GTI modules are undergraduate students who are taking a programming course in the computer science department. However, our proposed GTI modules can be used in introductory programming courses of graduate classes as well. For the development of GTI modules, we have considered both functional and non-functional requirement. The non-functional requirements are from the instructor's perspective, and the functional requirements are from a student's perspective.

The functional requirements are listed below:

1. The instruction in the GTI modules should be clear and concise. So, the undergraduate students can effortlessly understand the instruction and do not waste their time in aimless navigation through the GTI modules.
2. The GTI modules should be likable by the undergraduate students. The GTI modules should have more details. The GTI module should have graphics such as:(1) 3-D models, (2) buttons, (3) Images or picture (4) sound and (5) text. The graphics of GTI modules

should be appealing and eye-catching for all student. The GTI modules should be interactive and enjoyable.

3. The GTI modules should be usable. The undergraduate students should not face any technical difficulty while using the GTI modules.
4. The pseudocode of the binary tree and the linked list should be displayed on the screen. The goal of the GTI modules is to provide the learners high-level view of fundamentals of binary trees and linked list.
5. If the user (undergraduate student) gets tired of a game within any GTI module, the user should switch from that game to another without difficulty.
6. Students should be able to restart the GTI modules in case of system crashes, hang, or any other kind of technical difficulty occurs.
7. The students (end users) should be able to take help from the virtual instructor while interacting with the GTI modules.

The nonfunctional requirements are listed below:

1. The pseudo code and figures presented in the GTI modules should encourage undergraduate students to learn about linked list and binary trees. The GTI modules should motivate and engage the students in learning the fundamentals of programming concepts.
2. The GTI modules should be usable on any computer having windows operating system. The undergraduate students can use GTI modules (.exe file) on any computer (with windows operating system) which is available to them.
3. The GTI module should be less distracting by using examples related to the linked list or binary tree concept.



4. The GTI modules should implement a rewarding system that not only motivates the students but also grabs their attention. A scoreboard on the screen is an excellent example of a rewarding system. This enables the students to assess themselves during the learning process. Rewarding messages such as: "congratulation "or "good job.", will motivate and encourage the students to learn more.
5. In the GTI modules, the reaction to the student's input should be immediate. For example, if a student clicks on a button, there should be an immediate response from the software (GTI modules) because the waiting time could impair student experience. Game's responsiveness has a direct effect on the likability of the educational software tool.

### **3.2.2. Design consideration**

The game is designed from the revised 'Bloom's taxonomy.' We have utilized the "constructive approach of leaning" to design the GTI modules. We have applied the activity theory for modeling simulation-based learning in GTI modules. We have also incorporated an extended four-dimensional framework (FDF) for implementation. We have used plan-driven approach for the development of game theme-based instructional modules.

#### **3.2.2.1. Bloom's taxonomy**

The GTI modules follow the revised "Bloom's taxonomy" to help student's understanding of binary trees and linked list concepts. The revised Bloom's taxonomy [4] mentions problem-solving performance and success levels. The Bloom taxonomy promotes the various aspect of learning such as:

- Remembering the concepts

- Understanding the concepts,
- Applying the concepts
- Analyzing the concepts
- evaluating the concepts
- creating the concepts

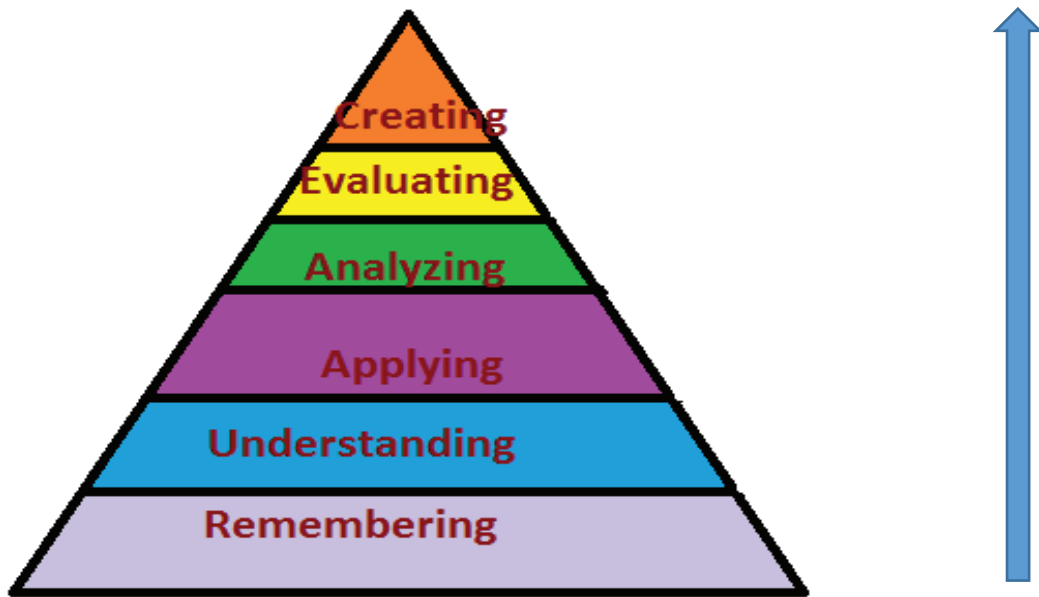


Fig. 9. Revised Bloom's taxonomy

According to revised Bloom's taxonomy, the concept is first remembered (define, recall, relate) then the students understand (compare, contrast, demonstrate, explain, extend, illustrate) the concept. After the students understand the concepts they apply (apply, build, choose, construct, develop, experiment with, identify) the concepts in the real situation. The concept is then analyzed (analyze, assume, categorize, classify, compare, conclusion, contrast, discover) and; after the analysis, the concept is evaluated (agree, assess, conclude, criticize, deduct, defend, determine, evaluate, explain, interpret, judge, justify). Finally, the learners create (adapt, build,

change, combine, compile, compose, construct, develop, discuss, elaborate, estimate, formulate, imagine, improve, makeup) the concept. In GTI modules the students can remember (recall) and understand the concepts by interacting with the virtual instructors. Students can apply their knowledge or experience it while playing the game. In GTI modules there are various opportunities for the students to analyze the concept they learn. Then students can evaluate their understanding and; create the concepts for themselves.

### 3.2.2.2. Constructive approach

The GTI modules are based on the constructive approach of learning, where the students acquire knowledge through experiencing it in the real world. In GTI modules students construct their understanding of linked list and binary tree while playing the games of GTI modules.

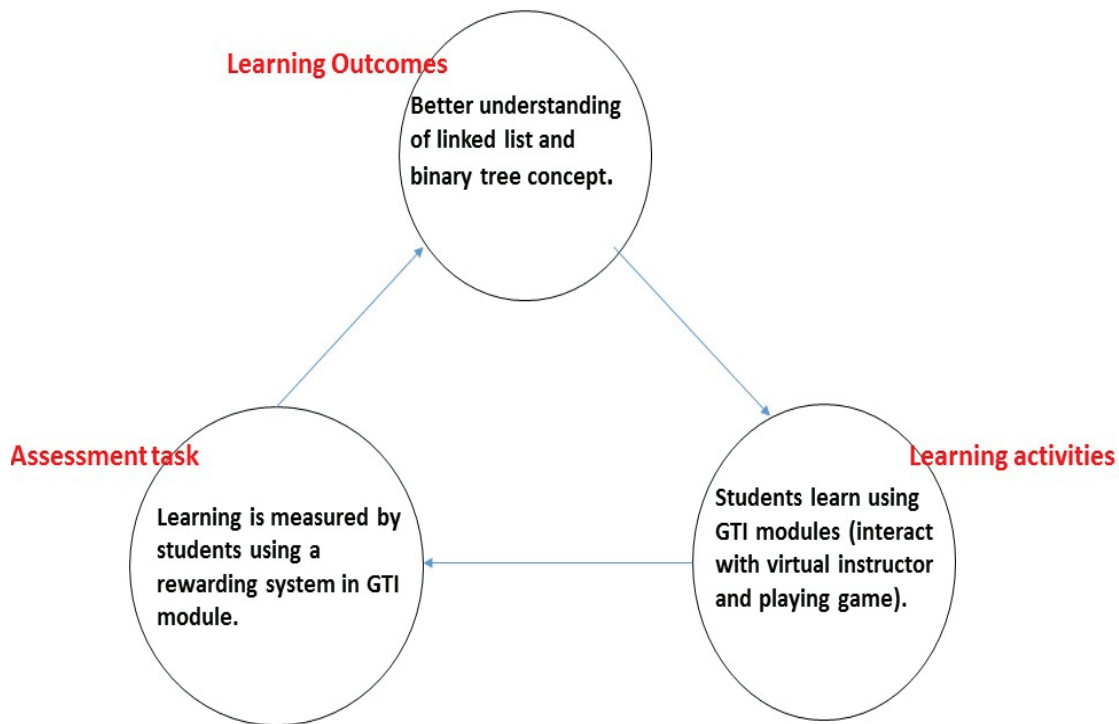


Fig. 10. Constructive alignment of GTI modules.

Figure 10 shows, the constructive learning approach as applied to teach undergraduate students of computer science using GTI modules. A better understanding of the linked list and binary tree concepts is the desired learning outcomes. We have considered gameplay of GTI module (interaction with a virtual instructor and playing game) as learning activities. The assessment tasks are the various games and pop up quizzes inside the GTI module. The rewarding system helps students to evaluate themselves while using GTI modules.

### **3.2.2.3. Activity system for GTI modules**

We have utilized the Kuutti's activity system [140] in GTI modules as follows (fig. 11):

1. Tool: GTI modules have non-immersive 3D-interface, high level of interactivity and, users can interact with a virtual instructor to clarify the concepts.
2. Subject: Undergraduate students from computer science department who have taken introductory programming courses.
3. Object: The objective for GTI modules is to clarify the concept (binary tree and linked list). We want to motivate and engage the students in learning linked list and binary tree concepts.
4. Rules: We have utilized the constructive approach to learning, in GTI modules. The students construct their knowledge using gaming metaphor. We have used Bloom's taxonomy in the design of GTI modules.
5. Community: Our proposed GTI modules do not support group study.
6. Division Of labor: We have designed GTI modules to be used in the classroom or computer lab. However, students can use GTI modules at their home during leisure time.

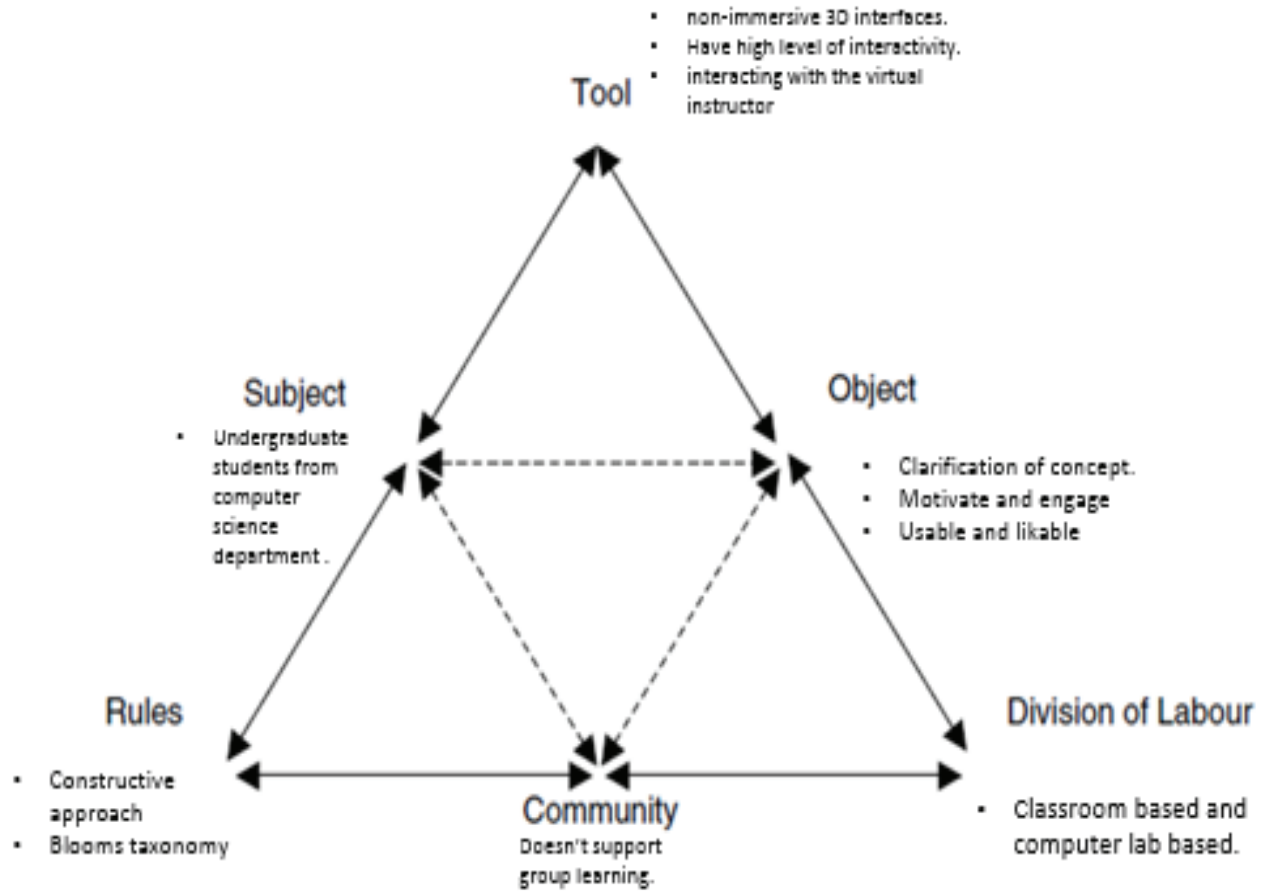


Fig. 11. Activity system for GTI modules

### 3.2.2.4. Extended FDF

We have adopted a proven framework with minor changes to measure the effectiveness of GTI modules. This framework inherits the primary triad of learning such as students, teacher, and tools. This framework is elaborated by reference to activity theory mentioned by Kuutti [140]. The Fig. 12 represents an iterative cycle - used as a framework to find the effectiveness of GTI modules. In this framework, there are four dimensions which we consider for the development of GTI modules. The first dimension of the framework includes the context where the learning takes place. The context includes classroom-based, outdoors accessibility, historical and political factors, and technical support. The second dimension emphasizes on learner's

specification. The learner's specification includes learning the background, a learner's individual or group profile. The third dimension emphasizes the mode of representation. The mode of representation includes the level of fidelity, interactivity, and immersion with GTI modules. The fourth dimension includes the approach to learning. This dimension includes learning theories, learning methods and learning models to produce better learning outcomes.

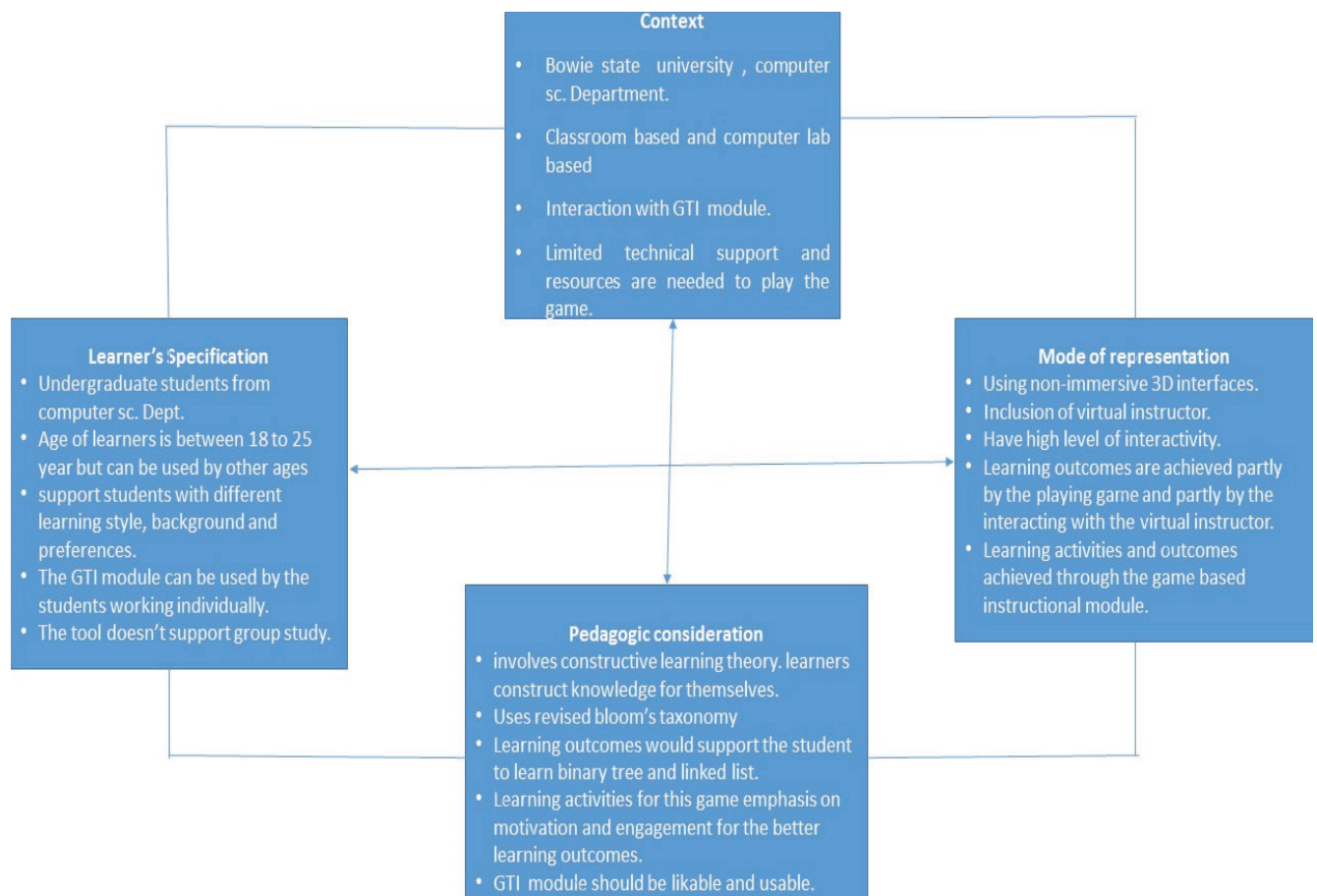


Fig. 12. Framework for finding the effectiveness of GTI modules.

The implemented system is a python application, which can be used as a learning tool to learn binary trees and linked list. The design and development of game theme-based instructional

module are aimed to demonstrate the concept of the linked list and binary trees data structure, to undergraduate students. The context for GTI modules is undergraduate and graduate classes of introductory programming courses. We have used constructive learning theory as pedagogic consideration. The mode of representation in our implementation was non-immersive 3D – interface. However, the GTI module was developed in Vizard environment so; the GTI modules can be converted into the immersive virtual environment using virtual reality hardware such as Oculus Rift.

Table VII. Checklist to find the effectiveness of GTI modules

<b>Context</b>	<b>Learner specification</b>	<b>Pedagogic consideration</b>	<b>Mode of representation</b>
CS students in undergraduate classes.	Undergraduate students from computer sc. Dept.	Involves a 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 a high level of interactivity.
Immersion and interaction in the 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	The tool does not support group study.	Briefing/debriefing should have been implanted into the game to achieve learning outcomes and motivate students to learn more.	Learning activities and outcomes achieved through the game based instructional module.

Table VII represents the same framework shown in fig. 12, in checklist style. We have incorporated table VII for the design and development of GTI module.

### 3.2.2.4.1. Context

The first dimension of the framework focuses upon the context where the learning takes place (fig. 12). The GTI modules can be used as a supplement to classroom-based learning. The context for GTI modules is undergraduate students of computer science department who are taking programming language courses. The context of GTI modules is classroom-based and computer lab-based (as shown in fig. 12). We need limited technical support to use the GTI modules as we use very basic computers peripherals such as the speaker and headphone to play with the GTI modules.

The macro level factors considered as context are:

- Historical
- Political
- Economical

Context is one of the essential factors to consider during the development and implementation due to the following reasons:

- Context can be an enabling factor for the learner's support.
- Context can provide significant impediment to delivery.

Even though we have developed the GTI modules for classroom-based context, the use of GTI modules is not limited to the classroom. This educational software tool is platform independent. So, this software (GTI module) can be used outside the classroom. In other words, the game theme-based instructional modules are outdoor accessible and; not limited to the classroom and computer lab. The students should be able to restart the GTI module if the system



crashes or hangs. Due to the accessibility of the software, the students do not need any technical support.

GTI modules are non-immersive software tools developed in Vizard. This enables us to quickly change this software tool to an immersive software tool using virtual reality hardware tools such as Oculus Rift. We do not have enough hardware available for all students. We have decided to develop the non-immersive educational software tool due to lack of special hardware required for the immersive software tool. The availability of a resource such as the number of Oculus Rift can improve the effectiveness of GTI modules.

The context for the development of GTI modules is undergraduate classes in the computer science department where they support undergraduate programming class curriculum with limited technical support and resource are needed to play these GTI modules.

#### **3.2.2.4.2. Learners specification**

The second dimension of the framework focuses upon the attributes of learners. Before designing or developing the GTI modules (educational software), we need to decide the learners or users of the educational software tool. The users or learners of GTI modules are undergraduate students from the computer science department.

The game theme-based instructional modules are intended for individual students learning. The GTI modules do not support group study. Fig. 12. Shows the learners' specification in checklist style. According to Bruckman [133], children and adolescent are fascinated by games. It has been widely acknowledged that computer games are part of the culture of many adolescents. We developed GTI modules for an adolescent of ages 18 to 25 years.

The background and the learning history of the students is also an important factor which

affects the effectiveness of GTI modules. The GTI modules support the students of different learning background/style. There are various levels of the game in each GTI module (binary trees or linked list). The students can choose the game according to their preference and learning style. There is a vast range of different learners coming from different majors and backgrounds. All students who participated in user study had already taken a prior programming course. Even though the game-theme based instructional module is primarily developed for undergraduate students, this tool can be used by others who want to learn programming concepts (binary trees and linked list) in an informal setting.

The virtual instructor in the GTI modules supports the learning and provide continuous help in the understanding of definition and examples in the binary tree and linked list modules. The students can ask for help anytime from the virtual instructor.

#### **3.2.2.4.3. Pedagogic consideration**

The third dimension of the framework focuses on the pedagogic consideration. As shown in fig. 12, we have used constructive theory to design and develop the GTI modules. The constructive learning theory states that the learners construct the knowledge by experiencing it in the real world. When the undergraduate students of computer science department use GTI modules for learning the concepts of binary trees and linked list; they interact with the GTI module and learn through their experience.

The GTI modules can provide a better understanding of binary trees and linked list concept than traditional instructional methods. The GTI modules motivate and engage the students and therefore produce better learning outcomes. In the traditional approach, each student may need a different level of attention from the tutor/lab instructor. The students without virtual reality game

experience may need extra attention regarding how to navigate through the GTI modules than the students having experience of virtual reality games.

We have also considered the curricula objectives for the development of GTI modules. The curricula objective for the GTI modules are as follows:

- Understanding of types of a linked list such as (1) singly linked list. (2) doubly linked list and (3) circular linked list.
- Understanding of function of the linked list.
- Understanding of basic terms in binary trees such as parent node, child node, leaf node, left and right subtree.
- Understanding of the complete tree, full tree, and partially filled tree.
- The function of binary trees such as insertion, deletion, and search.
- The concept of traversing a binary tree such as (1) preorder traversal (2) postorder traversal and (3) in order traversal.
- Concepts of the binary search tree.

The learning activities of GTI modules emphasize the clarification of the concepts of binary trees/linked list and to produce better learning outcomes. The learning activities include:

1. Interacting with the virtual instructor.
2. Navigating through the GTI modules.
3. Playing the gaming metaphor of GTI modules.

The games in the GTI modules incorporate a rewarding system to provide an insight into their learning progress. The award system of GTI modules can motivate the students towards learning.

We have also used briefing/ debriefing to reinforce learning outcomes. The briefing/debriefing

occurs before and after the gameplay of GTI modules. The gameplay and interacting with the virtual instructor is the learning activity (briefing) to produce better learning outcomes (debriefing). The post-activity reflection is noted using a post-survey right after the students use the GTI modules.

#### **3.2.2.4.4. Mode of representation**

The fourth dimension of the framework emphasizes the mode of representation or tool for use. Indeed, this dimension focuses on the processes of learning. This dimension considers model, approaches, and theories to support learning. Mode of representation includes:

- How GTI modules are embedded in the learning context.
- How GTI modules facilitate the learning theory or approach.

GTI modules use a medium level of fidelity based upon use of non-immersive 3D interfaces. The GTI modules have the high level of interactivity. Though the use of buttons in the GTI modules, the learners interact with the virtual environment using mouse clicks and keyboard commands.

The way the students can interact with the GTI modules are listed as follows:

1. Students can ask for help from the virtual instructor using the "help" buttons. They can go to the main menu and switch to another game anytime.
2. During gameplay, if the students need to learn about the dedicated concept, then the students can end the game and ask the virtual instructor (using mouse and keyboard command) for the better understanding of the concepts.
3. Students can skip the tutorial if they are already familiar with the concept and directly move to the game of their choice.

4. Students can also answer the pop-up questions during gameplay. These questions are part of the rewarding system, and there is a scoreboard which displays the student's score. So, the students can evaluate themselves while learning.

The learning activities and outcomes are achieved partly by playing games and partly by the interaction with the virtual instructor. The GTI modules use a medium level of realism regarding interaction in the 3D non-immersive virtual environment and with the virtual instructor. The GTI modules can be easily converted into an immersive virtual environment having a high level of realism using virtual reality hardware devices such as Oculus Rift.

The connection between GTI modules and reflection upon the learning of concepts of binary trees/linked list was the crucial aspect of this pilot study. The GTI modules aim to increase the motivation and awareness of the students through the engagement of learners in the learning process.

### **3.2.3. Implementation of GTI modules**

GTI modules to teach linked list and binary trees were developed using the world-viz Vizard, a virtual reality toolkit. Vizard is a python based integrated development environment which is used to create virtual reality applications. Python is a robust programming language with open source libraries and toolkits. The GTI modules were developed in two phases. In the first phase, we used 3D-max and sketch-up to model the 3D-environment. Then the 3D-environment was exported as an osgb/.dae file in Vizard for further development. In the second phase, we used the Python programming language in Vizard development environment to develop the game mechanics. We have used an in-built avatar as a virtual instructor, who helps the user to navigate through the GTI modules. We have also incorporated picture files (.jpg or .png) in the virtual

environment. We have used resources such as buttons, bullets, and logo to include interactivity for users inside the game.

### **3.2.3.1. Implementation of GTI module to teach linked list**

The linked list module is divided into three games: (1) Introduction of linked list, (2) Functions of linked list, (3) Concept of the doubly linked list. Each game in the linked list module starts with a tutorial on the corresponding topic. For example, the "Introduction of linked list" game would start with a tutorial on the creation of the linked list, description of types of linked list, definitions of the circular and doubly linked list. The instruction starts by describing the topic and then gives real-life examples to explain further the students understand the concepts related to the topic. All the tutorials were built with novice programmer in mind, but students who already know the concepts related to the topic can skip the tutorial (by pressing a skip button displayed on the screen) and proceed straightaway to the game. Various activities and challenges in each gaming module help the students to construct knowledge through gaming metaphors. The GTI module to teach linked list was developed with two aim in mind: usability and likability. GTI modules are appealing to the students, but it is possibly complicated for the students who are new to virtual reality games. Students experience little or no technical difficulties while using the GTI modules. Even novice players/users of virtual reality game do not have any problem in using the gaming modules. The students can read the instruction about "how to proceed" on the screen in each game. Students can also hear the audio having the same contents as the text. The text to audio conversion was done using <https://www.text2speech.org/>. We have added 3D models, avatars, text and, pictures, to make the module more appealing to the user and to enhance the user's experience. So, the GTI module is usable and likable.



Fig. 13. 3D-avatar who greeted and introduced the GTI module.



Fig. 14. The main menu shows the three-instructional module of the linked list.

When the students start the GTI module to teach linked list, they are greeted by an avatar (fig. 13) who gives a brief overview of the GTI module (using text and audio) and the main menu. As

shown in fig.14, the users have three option to choose a game based on their level of knowledge/interest. When the students click on any of the three options, within five seconds the game based on their choice will begin. There is also a "virtual instructor help," which is steady on the screen and; the students can press the help button to find out "how to proceed" at any time (fig 15).

(1) Introduction of linked list module: In this module, the user is acknowledged with the brief overview of the concepts related to the introduction of a linked list. A 3D avatar of the virtual tutor explains (using text and audio) the basic concepts related to a linked list in brief. Users get the instruction on the screen on how to proceed. The students can press "enter key" to go to next screen. There is a real-life example of the train to show the linked list. Students can add the cars to the trains and construct their knowledge on how to create a linked list (fig.15).

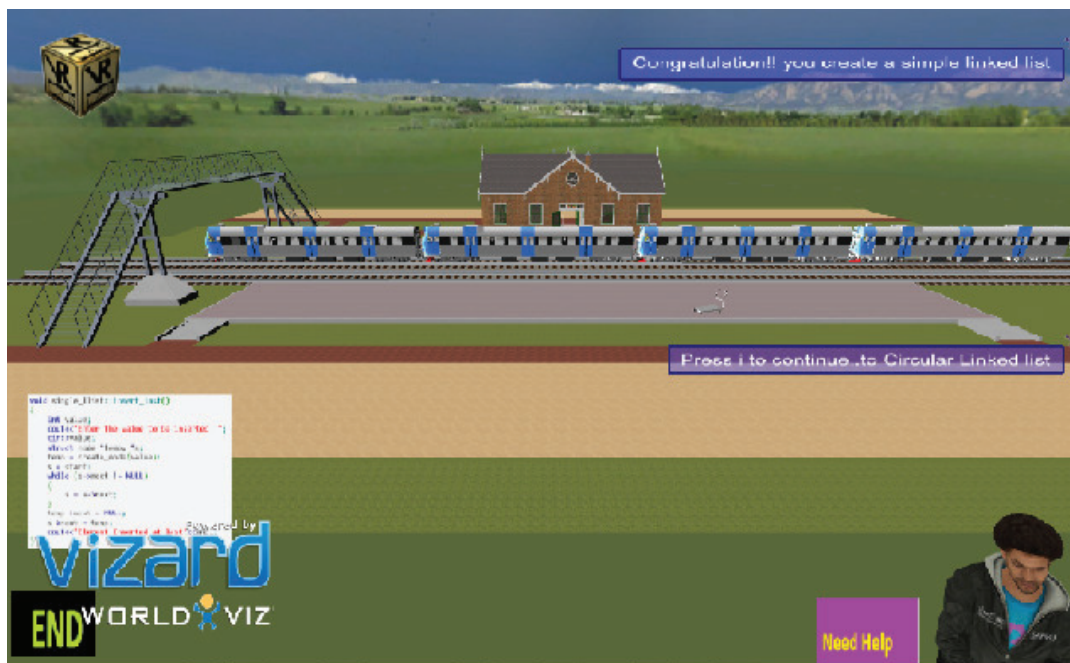


Fig. 15. Real-life example of the singly linked list.



We have also implemented a real-life example of the circular linked list by creating a group of woman standing in a circle. As shown in fig.16, all woman held each other's hand. Students can visualize that there is no null pointer (defined end) and can construct their knowledge about the difference between a linked list and circular linked list.



Fig. 16. A real-life example of the circular linked list.

(2) Functions of linked list module: In this module, the user is introduced with a brief overview of the concepts related to "function of the linked list." A 3D avatar of virtual tutor describes the concepts related to functions of a linked list. The students can press "enter key" to go to next screen. There is a real-life example of the train to show the functions of a linked list, such as (1) insertion (2) deletion (3) search or find. Students can insert the cars in the trains and construct their knowledge on how to insert in a linked list'(fig 17). As shown in fig 17, the students can insert a new node/car in the linked list (train) in three ways:

1) At the front of the linked list: add car A in front

- 2) After a given node: add car A after B
- 3) At the end of the linked list: add car A at end



Fig. 17. Insertion in the linked list.

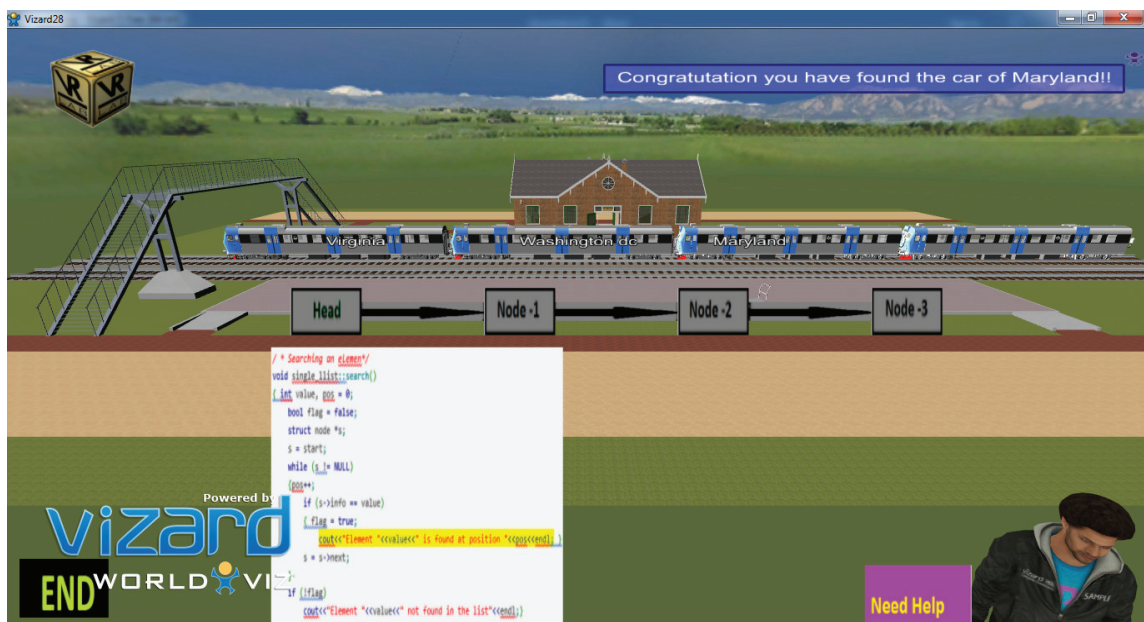


Fig. 18. Search (find the car of Maryland) in the linked list.

When the user chooses any of the three, they can visualize and experience the insertion of the linked list. We have also implemented a game for deletion and searching a node in the linked list using the real-life example train. From fig 18, we can see user/player/student needs to find the car that belongs to "Maryland." The users can visualize how to traverse the list/train to find the node/car.

- (3) Doubly linked list module: In this module, the user is acknowledged with a brief overview of the concepts related to "doubly linked list." A 3D avatar of the virtual tutor describes the concepts related to the doubly linked list (refer fig.19). The students can press "enter key" to go to next screen. There is an interactive button to show the functions of the doubly linked list, such as (1) insertion (2) deletion (3) search or find.

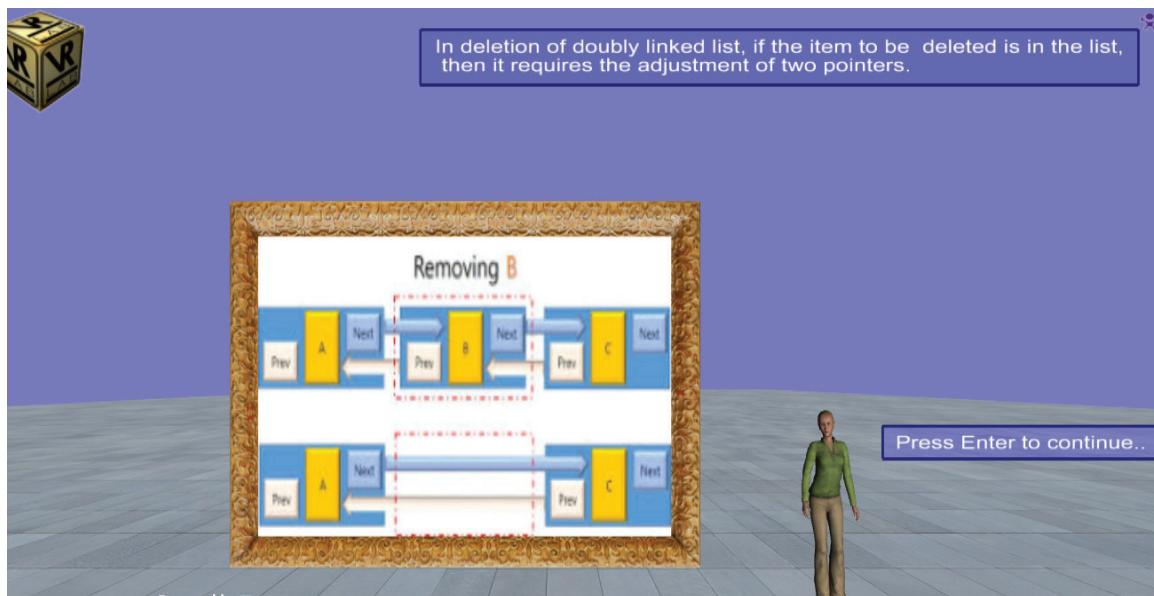


Fig. 19. A virtual tutor describes the concept related to the doubly linked list.

### 3.2.3.1.1. Flow Chart for GTI modules to teach linked list

The GTI module is comprised of three games: one for teaching introduction of a linked list, second for teaching functions of a linked list, and a third one for teaching the concept of the

doubly linked list. When the user selects a topic/game, it starts in five seconds. The countdown of 5..4..3..2..1 will display on the screen and enhances the curiosity of users. 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. When they do the activity/challenge correctly, they can proceed to the next challenge. The flowchart for gameplay in the GTI module to explain linked list is shown in Fig. 20.

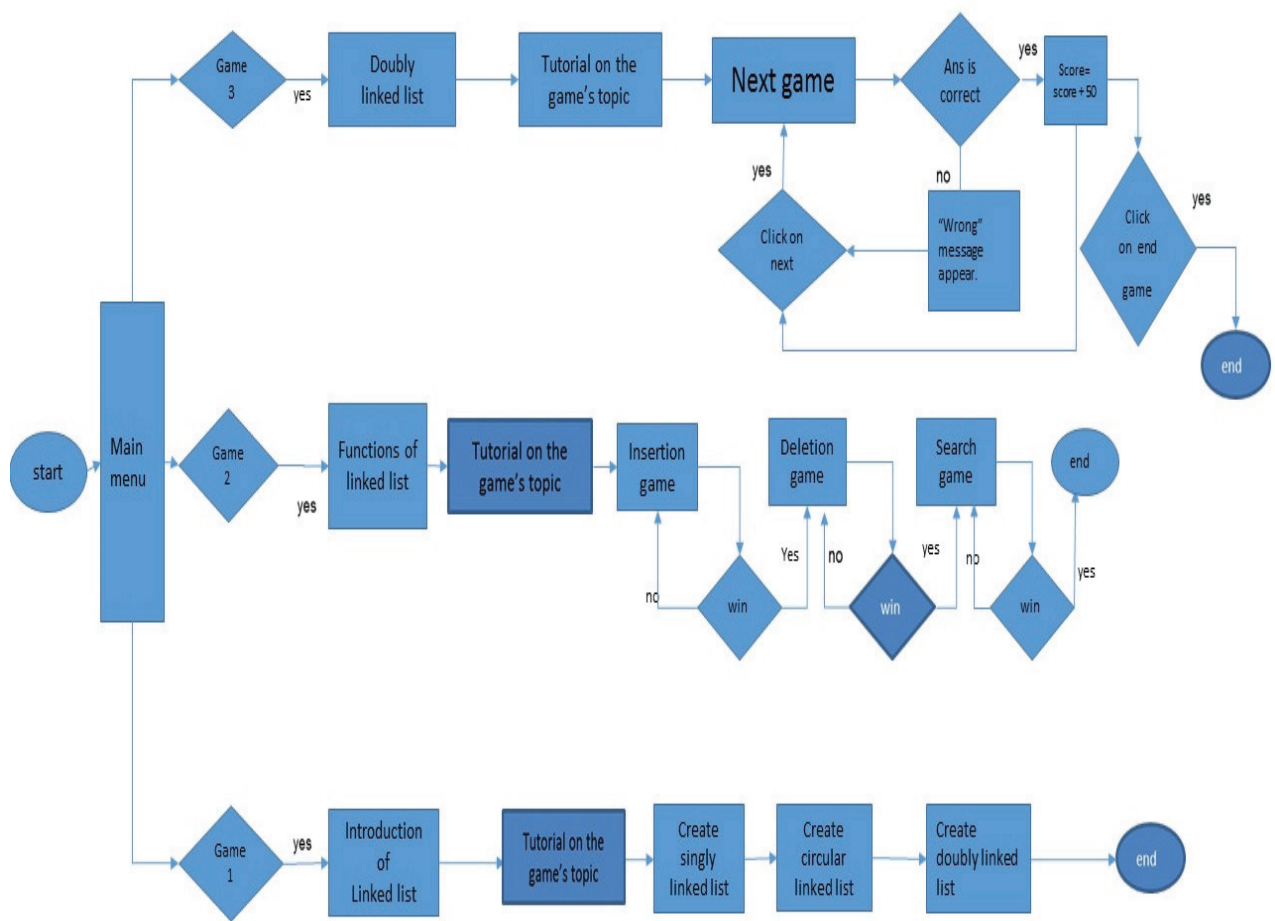


Fig. 20. Flowchart of GTI module to teach linked list

In the first game, users get an experience of creating a singly linked list. We have used the train as a real-life example to show the creation of the singly linked list. Then the users can click on

the next button to go to the following screen where they can experience the creation of the circular and doubly linked list. In the second game, the users experience the functions of the linked list. The users can add/insert an element (a car) in the linked list (a train) and also visualize the deletion and search process of the linked list. In the doubly 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 the 'end button.' When they click on the end button, they will reach to the main menu screen.

### 3.2.3.1.2. GUI for linked list modules

We have used different interface elements to make the linked list modules more attractive. The GUI for gameplay in the GTI module to teach linked list is shown in Fig. 21. We have utilized the following GUI elements to make our modules more appealing:

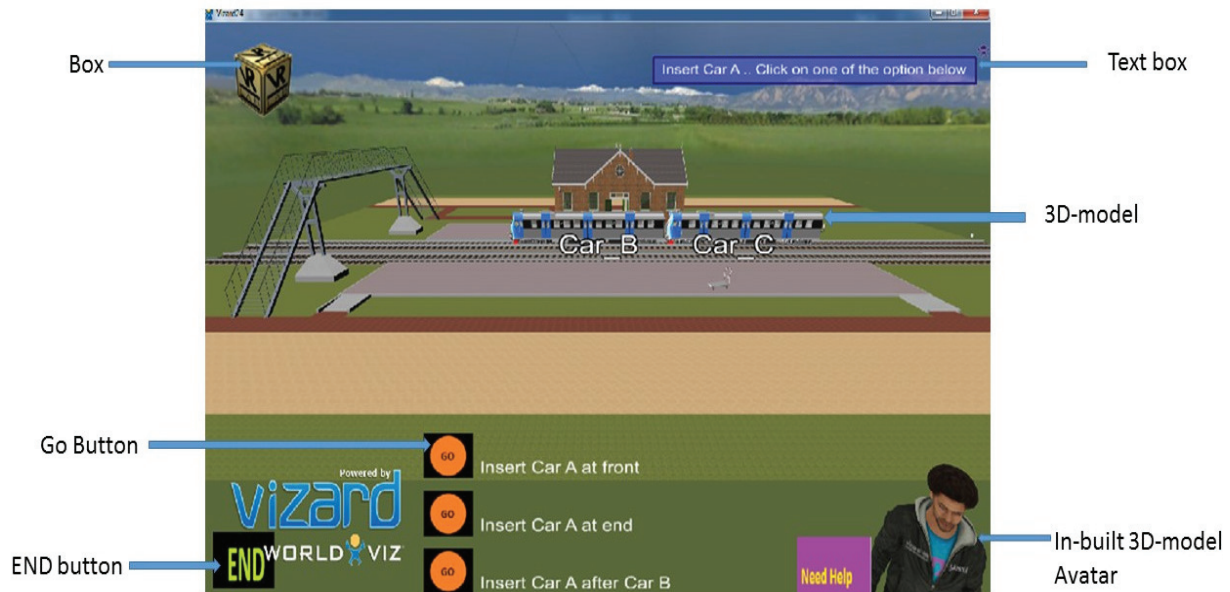


Fig. 21. Assorted interface elements of GTI modules to teach linked list

```

Vizard26.py - Vizard 5 Free (64-bit)
File Edit View Script Debug Window Tools Help
Vizard26.py x Vizard30.py Vizard27.py
858 #Add CONCEPTS OF LINKED LIST button
859 Game1 = viz.addButton()
860 Game1.uppicture('go.png')
861 Game1.downpicture('go1.png')
862 Game1.setPosition(.25,.65,0)
863 Game1.setScale(1,1,1)
864
865 vizact.onbuttondown(Game1,Pick2,1)
866
867 #Add CONCEPTS OF LINKED LIST label
868 first2 = viz.addText('INTRODUCTION OF LINKED LIST',viz.SCREEN)
869 first2.setPosition(.27,.65)
870 first2.setScale(.26,.26,.2)
871 first2.setBackdrop(viz.BACKDROP_OUTLINE)
872
Ready Game Ln 858 Col 26 INS

```

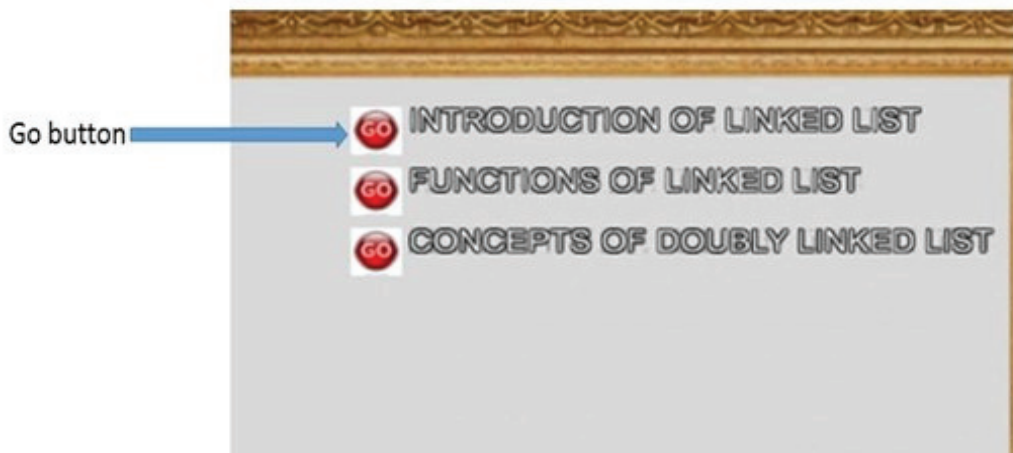
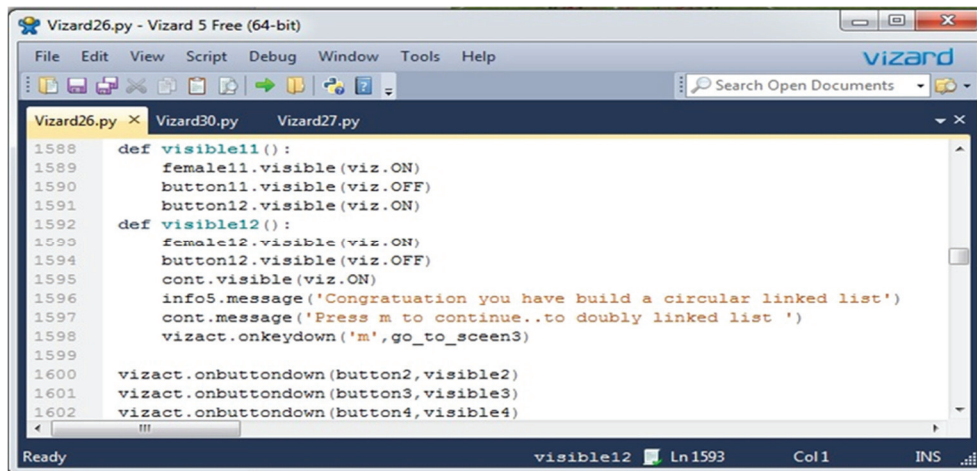


Fig. 22. Screenshot of source code in python and an output screen of the "GO" button.

- Buttons: We have used a range of buttons to make the gameplay more appealing, such as (1) GO button, (2) Help button, (3) Next button and (4) End button. We have used "GO button" for choosing between given options. The implementation of "Go Button" is shown in fig. 22. The "help" button is used to clarify the queries of the users. We have added "help" button to get help from the virtual instructor. We have exploited the "Next"

button to go on next screen and; the "End" button to end the gameplay and move on main menu page/screen.

- Boxes: We have incorporated boxes to shows the linked list module is virtual reality-based gameplay. As shown in fig.21, a box is used to display the GTI module in VR based gameplay.
- 3D- models: We have incorporated 3D-models to make the linked list modules more appealing. We have created the 3D models using 3D Max and SketchUp and imported them in Vizard. As shown in fig.21., we have an assortment of 3D-models. We have also incorporated an in-built avatar of Vizard to make the gameplay more likable.



```
1588 def visible11():
1589     female11.visible(viz.ON)
1590     button11.visible(viz.OFF)
1591     button12.visible(viz.ON)
1592 def visible12():
1593     female12.visible(viz.ON)
1594     button12.visible(viz.OFF)
1595     cont.visible(viz.ON)
1596     info5.message('Congratuation you have build a circular linked list')
1597     cont.message('Press m to continue..to doubly linked list ')
1598     vizact.onkeydown('m', go_to_sceen3)
1599
1600 vizact.onbuttondown(button2, visible2)
1601 vizact.onbuttondown(button3, visible3)
1602 vizact.onbuttondown(button4, visible4)
```

Fig. 23. The screenshot of an implementation of text boxes to show "how to proceed" and "complement."

- Text Box: We have incorporated various "text boxes" to make the GTI modules more informative. A screenshot of source code (in python) and a corresponding screenshot of "text boxes" in gameplay is shown in fig.27 and fig.28. We can see, the "text boxes" make the GTI modules more usable as the user can take help from the "text." The users also receive a compliment from the text boxes such as: "good job" and "congratulation."

From fig. (23, 24), we can see the screenshot of the implementation and the output screen of text boxes.



Fig. 24. Text boxes to show "how to proceed" and "complement."

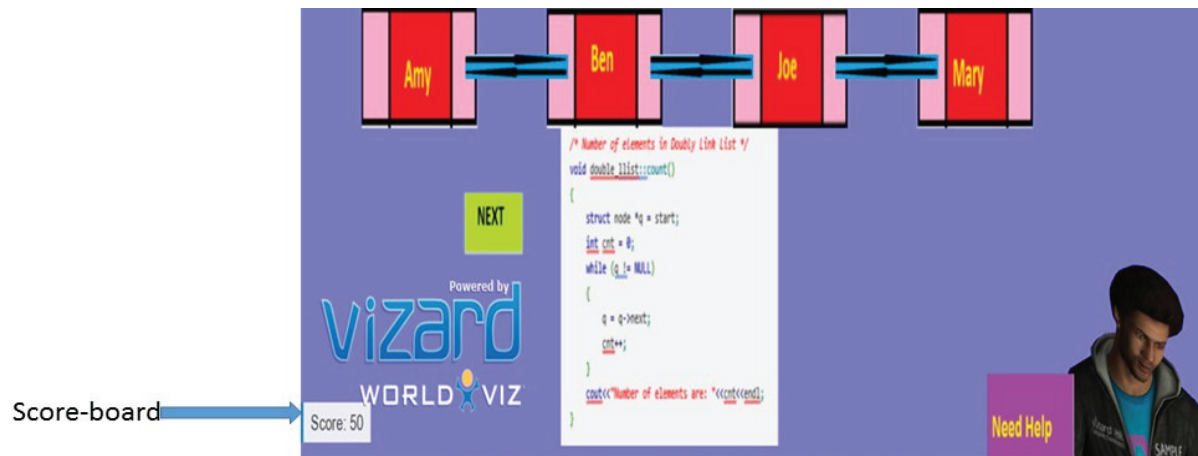
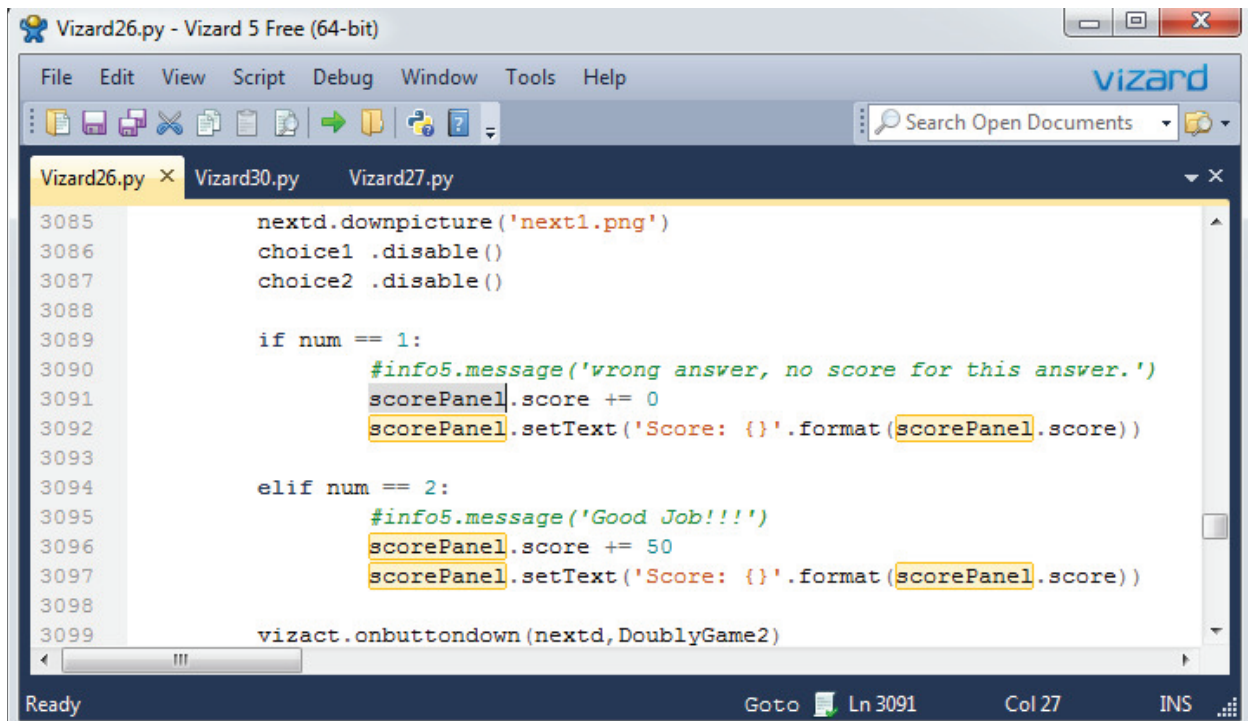


Fig. 25. Score-board to display the score of users

- Scoreboard: There is a scoreboard incorporated in the gameplay to display the score of the users. When the users complete an activity or challenge, then the score is incremented



by "50" points, and the scoreboard displays the score of the candidate. We can see the scoreboard and its implementation in fig. 25 and fig. 26.



```
Vizard26.py - Vizard 5 Free (64-bit)
File Edit View Script Debug Window Tools Help
Vizard26.py x Vizard30.py Vizard27.py
3085     nextd.downpicture('next1.png')
3086     choice1 .disable()
3087     choice2 .disable()
3088
3089     if num == 1:
3090         #info5.message('wrong answer, no score for this answer.')
3091         scorePanel.score += 0
3092         scorePanel.setText('Score: {}'.format(scorePanel.score))
3093
3094     elif num == 2:
3095         #info5.message('Good Job!!!')
3096         scorePanel.score += 50
3097         scorePanel.setText('Score: {}'.format(scorePanel.score))
3098
3099     vizact.onbuttondown(nextd, DoublyGame2)
Ready Goto Ln 3091 Col 27 INS
```

Fig. 26. The source code for the scoreboard.

- Pseudo code: The pseudocode of the linked list is displayed on the screen. The goal is to provide the learners high-level view of fundamentals of the linked list. The GTI modules should motivate and engage the students in learning linked list concepts. The pseudo code and figures presented in the GTI module encourage the students to learn more about the linked list.

### 3.2.3.1.3. Implementation of virtual instructor for linked list module

We have incorporated virtual instructor in the linked list (GTI) module to make the modules more functional and descriptive. There is a steady virtual instructor who helps the users/students while using the gaming module. We have used an inbuilt 3D avatar (having inbuilt animation) in

Vizard as a virtual instructor. The virtual instructor is accessible throughout the gameplay. The users can inquire from the virtual instructor by clicking on the help button. When the users click on the "help" button using the mouse, then three kind of help button becomes visible which include: (1) How to proceed, (2) educational content related to the game and (3) Navigate about the next screen. The virtual instructor for gameplay in the GTI module to teach linked list is given in Fig. 27. As shown in fig. 27., the users can ask for help by clicking the mouse on "help" button, and they can choose their query from any of the three options. When the users click on either of the three options, then the virtual instructor clarify their query. We have included audio files (.wav) to generate the virtual instructor voice. So, the virtual instructor appears more realistic and appealing. We have also incorporated "text boxes" besides the virtual instructor, which are visible on the screen when the virtual instructor speaks and clarify the user's inquiry. These text boxes are the textual version of virtual instructor speech. There is a 'Go back' button, which becomes visible when the user clicks on either of three help buttons. The 'Go back' button is used for going back and stop the virtual instructor speech.

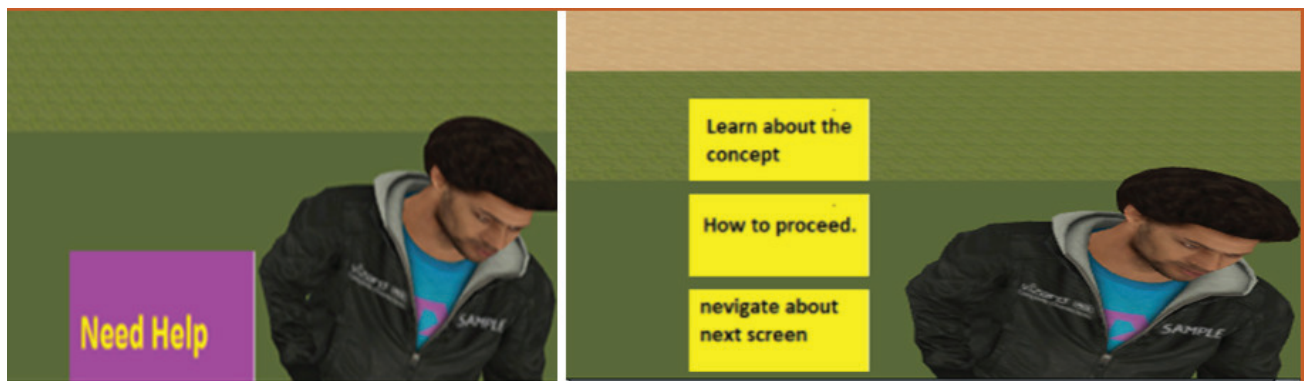


Fig. 27. Virtual Instructor used in the linked list instructional module

### 3.2.3.2. Implementation of GTI module to teach Binary trees

The binary tree module is divided into three games, each discussing one topic related to the binary tree, such that: (1) Terminology in binary tree, (2) Functions of binary tree, (3) Concept of a binary search tree. Each game in the binary tree module starts with a tutorial on the corresponding topic. For example, the "Terminology in binary tree "game would start with a tutorial on the terminology of the binary tree, description of types of binary trees, definitions of full and complete binary tree. The instruction starts by describing the topic and then gives real-life examples to explain further the students understand the concepts related to the topic. We have built the tutorials with novice learners in mind, but if the students already know about the concepts related to the topic (binary tree), they can skip the tutorial by pressing a skip button displayed on the screen and proceed straightaway to the game.



Fig. 28. A 3D-avatar who greets and introduces the GTI module to teach the binary tree.

When the students start the GTI module to learn binary tree, they are greeted by an avatar (fig. 28). Then the avatar gives a brief overview of the GTI module and asks the users to press

spacebar to proceed to the main menu. As shown in fig.29, the users have three option to choose a game based on their level of knowledge/interest. When the users/students click on any of the three options; within five seconds the game based on their choice will begin.



Fig. 29. The main menu is showing the three-instructional module of the binary tree.

(1) Terminology in binary tree module: In this module, the user is acknowledged with a brief overview of the terminology used in the binary tree concepts. A 3D avatar of the virtual tutor explains the basic concepts related to binary trees in brief. Users get the instruction on the screen about "how to proceed." The students can press "enter key" to go to next screen. We have incorporated an in-built avatar as a virtual tutor, who helps the user to learn about the GTI modules (as shown in fig.30).

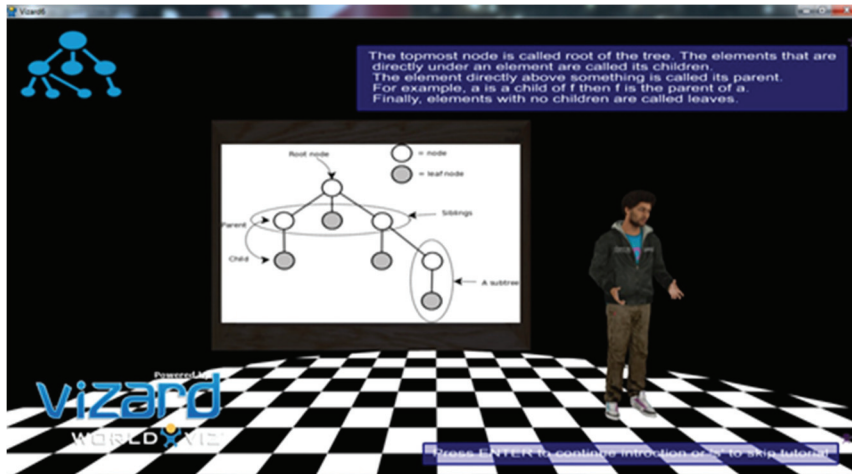


Fig. 30. In-built avatar as a virtual tutor.

We implemented an interactive model (using Buttons) of the binary tree by creating a group of buttons displayed as a tree. As shown in fig.31, when the user clicks on the right node/button. They get a rewarding message, and 50 points increase in their score. After finishing the challenge, the users can click on the next button to move to the next challenge/activity. Students can ask for help from the virtual instructor by clicking on the help button.

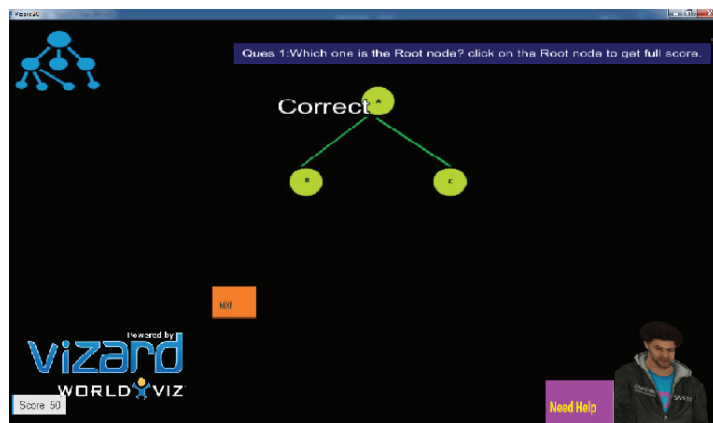


Fig. 31. Interactive initial model of binary tree

(2) Functions of linked list module: In this module, the user is acknowledged with a brief

overview of the concepts related to "function of the binary tree." A 3D avatar of virtual tutor describes the concepts related to functions of a binary tree in brief. The students can press "enter key" to go to next screen. There is an interactive model of binary trees to show the functions of binary trees, such as (1) Traversal (2) insertion (3) deletion. Students can traverse the binary tree using the interactive binary tree model and construct their knowledge 'how to traverse in a binary tree. We can traverse the binary tree in three ways:

1. Pre-order traversal
2. In-order traversal
3. Post-order traversal

There is three separate game for the three-different kind of traversal. Students get the instruction and hint to traverse the tree in a specific manner. If they click on the correct node, it will turn red from green (as shown in fig.32). If they do not click on the correct node (don't follow the traversal rule), then they will be stuck on the screen until they will do it correctly. There is an end button on each screen. If the users want to exit from a game, then they can click on the end button, which takes them to the main menu page. There is also a steady virtual instructor. Users can ask for help from the virtual instructor anytime. There is a pseudocode displayed on the screen to provide the user with a high-level view of the binary tree. When the user clicks on a correct node, the related pseudo code will be highlighted. So, the user can construct their knowledge about the programming of binary trees.

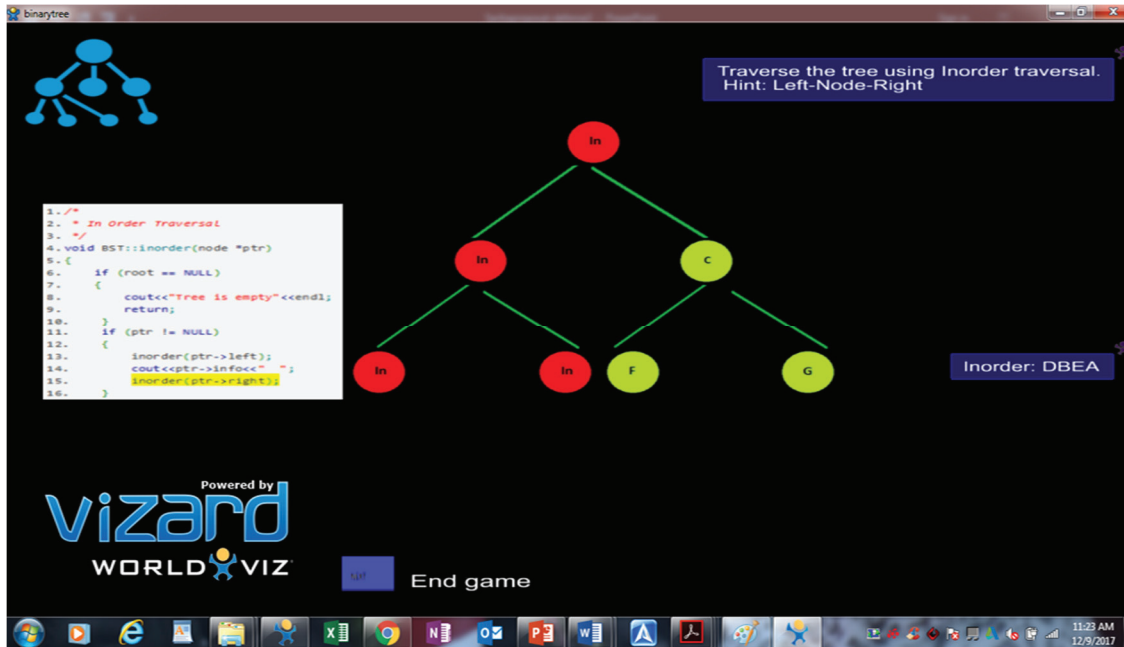


Fig. 32. In-order traversal of binary tree

Students can insert the nodes in the interactive model of a binary tree and construct their knowledge 'how to insert in a binary tree' (fig. 33).

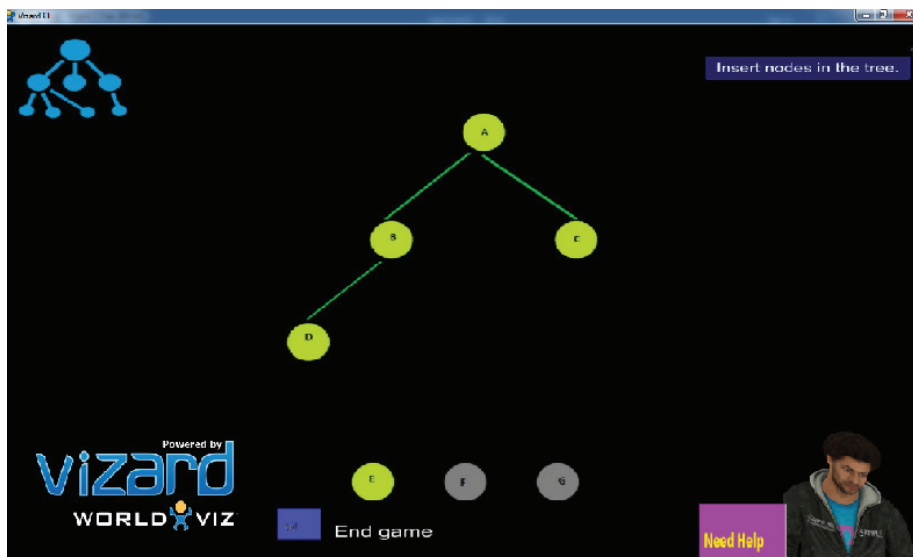


Fig. 33. Insertion in a binary tree

When the user chooses any of the three, they can visualize and experience the insertion of the

binary tree. We have also implemented a game for deletion of a node in the binary tree using the interactive buttons.

(3) Binary search tree: In this module, the user is acknowledged with a brief overview of the concepts related to "Binary search tree." A 3D avatar of the virtual tutor describes the concepts related to binary search tree in brief. The students can press "enter key" to go to next screen. The binary search tree is a special kind of binary tree, which keep its nodes in sorted order. We have developed a binary search tree using interactive nodes having small numerical values as its value (refer to fig. 34). We have used these interactive buttons to show the functions of binary search trees.

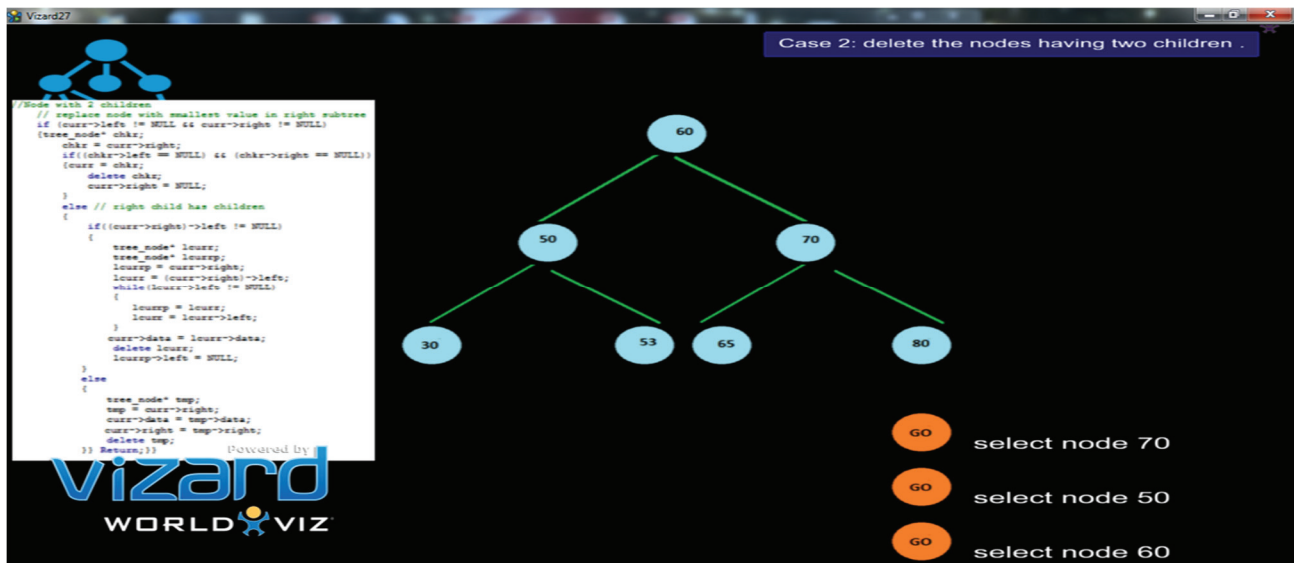


Fig. 34. Deletion from the binary search tree

### 3.2.3.2.1. Flow Chart for GTI modules to teach binary tree

The flowchart for gameplay in the GTI module to teach binary tree is given in Fig. 35. The GTI module is comprised of three games: one teaching terminology in the binary tree, another teaching functions of a binary tree, and a third one teaching the concept of the binary search tree.



When the user selects a topic/game, it starts in five seconds. The countdown ( 5..4..3..2..1) displays on the screen and enhances the curiosity of users. 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 the next challenge. In the first game, users get an experience of learning about terminologies in a binary tree. In the “terminology” game, users get quizzes/challenges/activities based on the concepts of binary trees. They can proceed to next screen/challenge by clicking on next button. They can exit from the game using the end button. When they click on the end button, they will reach to the main menu screen. We have used interactive buttons to show the creation of the binary tree. In the second game, the user gets the experience of functions of a binary tree. When the users click on the second game, he will get a challenge for Preorder traversal of the tree. If the user completes the challenge, he will get instruction on how to proceed. Then the user will get a challenge of "in order traversal," if he completes the challenge the user will go to the next level; otherwise he will be stuck on a screen. Then he will get a challenge of “post-order traversal" if he completes the challenge he will get instruction to go to the next screen. In the same way, he will get an activity for insertion and deletion in the following screens. Users need to finish all the challenge on one screen before the move to another. The user can exit from the game by clicking on the "end" button. When the user clicks on the third game, he will get tutorial on binary search tree. Then he will get the challenge of insertion in BST. If he successfully inserts the nodes in BST, he will get instruction to proceed to deletion of BST. There are three cases for deletion of a node from a binary search tree. In the gameplay, we have tried to explain all cases of deletion. The user can visualize the deletion process of the binary search tree. The user can click on “end button” anytime and exit from the game.

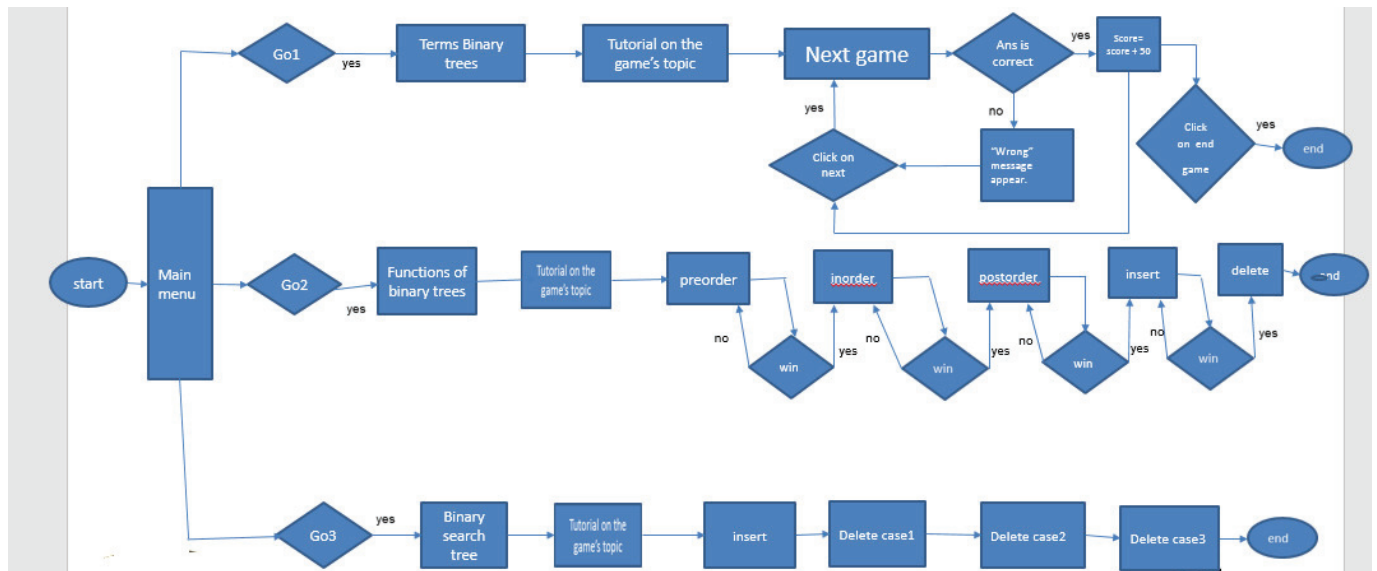


Fig. 35. Flowchart of GTI module to teach binary tree

### 3.2.3.2.2. GUI for binary tree modules

We have used various Graphical Users interface elements to make the binary tree modules more appealing. The interface elements for gameplay in the GTI module to teach binary trees is given in Fig. 36.

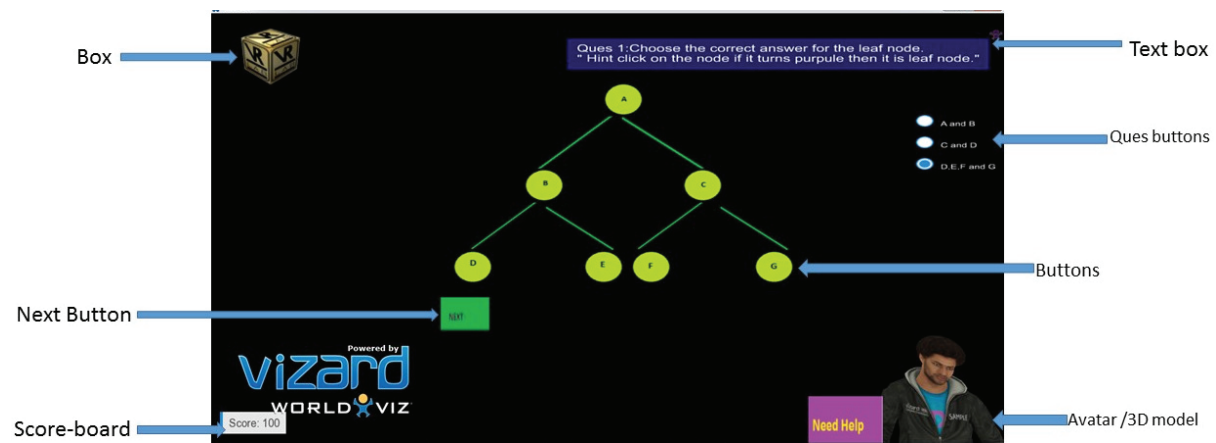


Fig. 36. Assorted interface elements of GTI modules to teach binary tree

We have used the following GUI to make binary tree modules more engaging:

- Buttons: We have used a range of buttons to make the GTI modules more revealing, such that (1) nodes of trees, (2) Go button, (3) Help button, (4) Next button and (5) End button. We have used "GO button" for choosing between given options. The implementation of" Go Button" is shown in fig. 37. The "help" button is used for clarifying the queries of the users. We have added "help" button to make the GTI modules more usable. We have exploited the "Next" button to go on next screen and; the "End" button to end the gameplay and move on main menu page/screen.

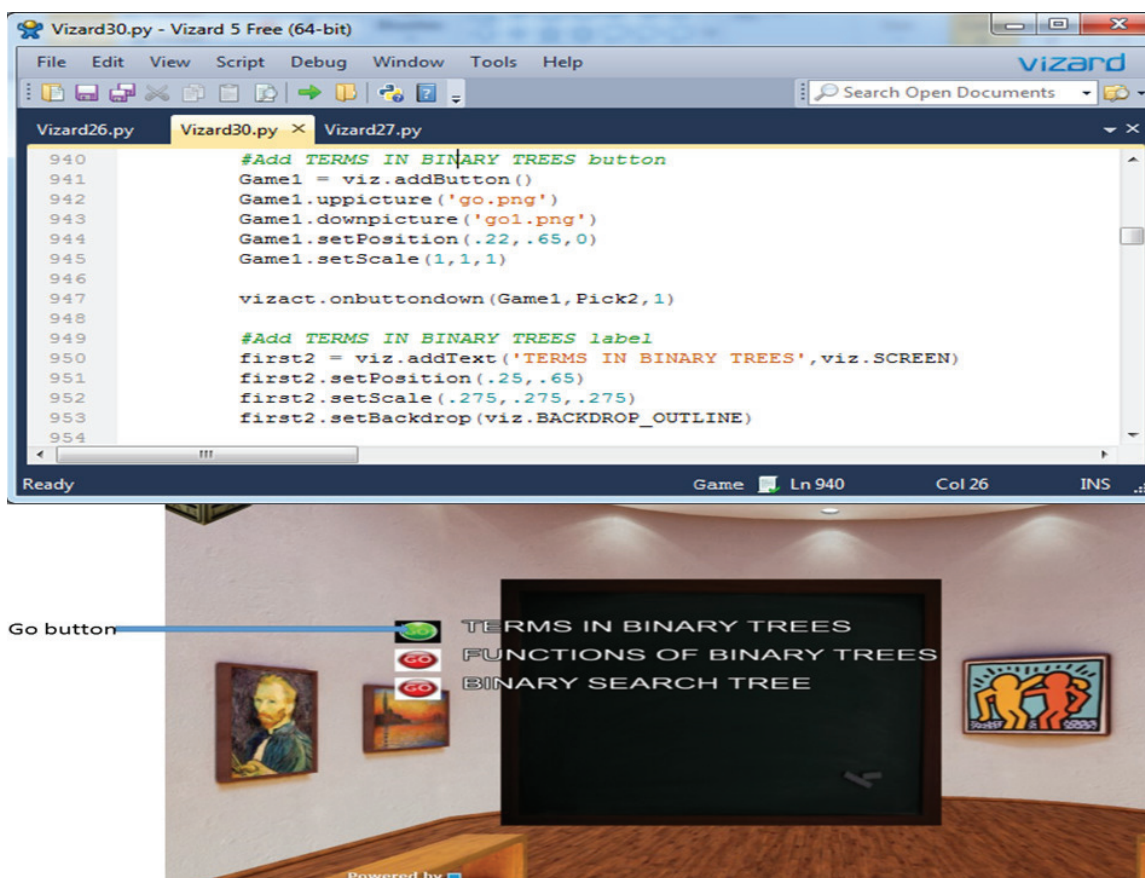


Fig. 37. Screenshot of source code and an output screen of the "GO" button

- Boxes: We have incorporated boxes to show the binary tree module is virtual reality-based gameplay. As shown in fig.36, a box is used to display the GTI module is VR based gameplay.
- 3D- models: We have exploited 3D-models to make the Binary tree modules more appealing. We have created the 3D models using 3D max and SketchUp and imported these models in vizard. As shown in fig.36., we have an assortment of 3D-models. We have also used in-built avatars of vizard to make the gameplay more appealing and likable.
- Text: We have incorporated various "text boxes" to make the GTI modules more informative. A screenshot of source code (in python) and a corresponding screenshot of "text boxes" in gameplay is shown in fig.38. We can see, the "text boxes" make the GTI modules more usable as the user can take help from the "text." The users also received a compliment using the text boxes such as: "good job" and "congratulation."

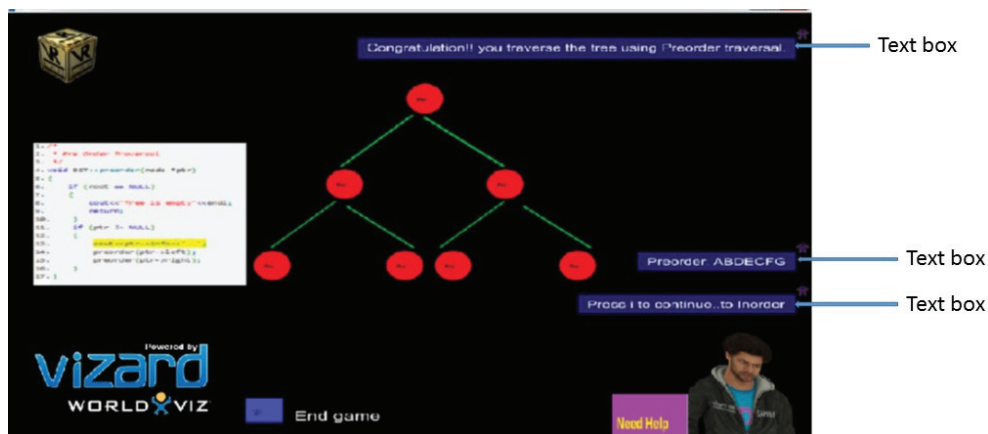


Fig. 38. Text boxes to show "how to proceed" and "complement."

- Scoreboard: There is a scoreboard incorporated in the gameplay to display the score of the users. When the users complete an activity or challenge, then the score is incremented

by "50" points, and the scoreboard displays the score of the candidate. We can see the scoreboard and its implementation in fig. 39.

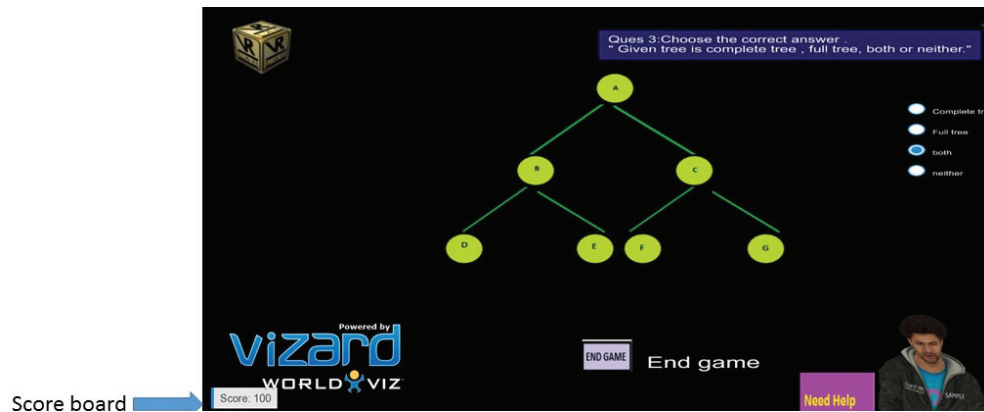


Fig. 39. Scoreboard and the source code for the scoreboard.

- Images of pseudo code: The pseudocode of binary tree is displayed on the screen (fig.38) The goal is to provide the learners high-level view of fundamentals of the binary tree. The GTI modules should motivate and engage the students in learning binary tree concepts. The pseudo code and figures presented in the GTI module encourage the students to learn more about the binary tree.

### 3.2.3.2.3. Implementation of virtual instructor for Binary tree module

We have incorporated the virtual instructor in the Binary tree (GTI) module to make the modules more realistic and user friendly. There is a steady virtual instructor which help the pupils while using the GTI module. The virtual instructors help the students in three way: (1) how to proceed or play current game (2) concept related to the current game (3) what will come after the current game. The virtual instructor for gameplay in the GTI module to teach Binary tree is shown in Fig. 40. As shown in fig 40, the users can ask for help by clicking the mouse on “help” button. Then three kinds of buttons display on screen and students can choose any of the three options.

When the users click on either of the three options, the virtual instructor clarifies their query about the learning module. We have included audio files (.wav) to generate the virtual instructor speech to make him appear real and engaging. We have also incorporated “text boxes” besides the virtual instructor in the GTI modules, which is visible on the screen when the virtual instructor speaks and clarify the user's inquiry. These text boxes are the textual version of virtual instructor speech. There is a ‘Go back’ button, which becomes visible when the user clicks on either of three help buttons. The ‘Go back’ button is used for going back and stop the virtual instructor speech.

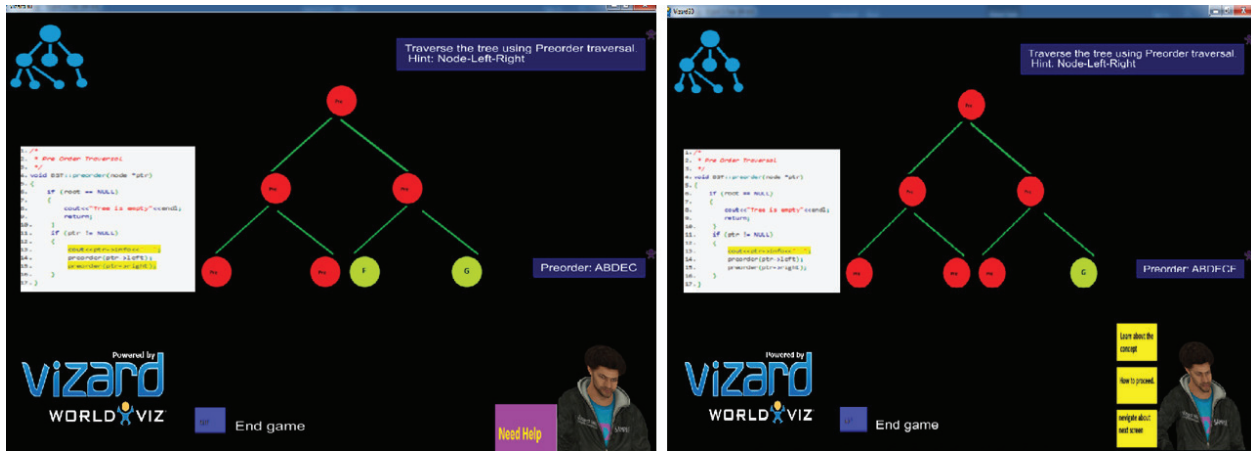


Fig. 40. Virtual Instructor used in the binary tree instructional module.

### 3.2.3.3. Implemented System

The implemented system is a python application, which is used as a learning tool to learn binary trees and linked list. The design and development of game theme-based instructional module are aimed to demonstrate the concept of the linked list and binary trees data structure, to undergraduate students. We have used FDF (four-dimensional framework) with a minor extension for design and development of GTI modules. The four dimensions of the framework include (1) context, (2) Learner specification (3) Pedagogic consideration (4) mode of

representation. Computer science undergraduate classes are considered as the context for the GTI modules. We have developed the GTI modules for undergraduate CS students; however, it can be used in introductory programming courses of graduate programs. The GTI modules are used individually and does not support group study. We have used constructive learning theory as pedagogic consideration. We have included the student's motivation and engagement as well as usability and likability of software tools (GTI modules) in pedagogical consideration. The mode of representation in our implemented system was a non-immersive 3D – interface. 3D models were created using 3D max (3D modeling and animation software tool), and models were imported in Vizard using python source code. We have included a virtual instructor in the mode of representation. The GTI module was developed in Vizard environment using python source code. The game theme-based instructional modules can be converted into the immersive virtual environment using virtual reality hardware such as Oculus Rift.

#### **3.2.3.3.1. Extended Four-Dimensional Framework**

We have incorporated an extended four-dimensional framework for the development of GTI modules.

1. The first dimension of the framework includes the context where the learning takes place. The context for our proposed GTI modules includes undergraduate classroom-based and lab-based. However, GTI modules can be used in introductory programming courses at graduate level. The GTI modules need limited or no technical support. So, the GTI modules can be used at the student's home during their leisure time.
2. The second dimension emphasizes on learner's specification. The learner's specification includes learning the background, the learner's individual or group profile. We have

developed the GTI modules for students from different majors, who have enrolled in an introductory programming course in computer science. The GTI modules do not support group study.

3. The third dimension emphasizes the approach to learning (pedagogic consideration). This dimension includes learning theories, learning methods and learning models to produce better learning outcomes. We have used the constructive approach of learning for the development of GTI modules. We also considered bloom's taxonomy for the design and development of GTI modules. We are further extending the framework by adding:

- Motivation and engagement in the pedagogic consideration: Our proposed GTI modules motivates and engaged the students towards learning the introductory programming concepts (linked list and binary tree).
- Usability and likability in pedagogic consideration: Virtual reality games are more attractive (likable) but complex for novice player/user of virtual reality games. So, we developed GTI modules which are attractive as well as uncomplicated/ easy to use.

4. The fourth dimension includes mode of representation. The mode of representation includes the level of fidelity, interactivity, and immersion with GTI modules. Our proposed GTI modules have a high level of interactivity. We have used non-immersive 3D interfaces for the development of GTI modules. We are further extending the framework by adding:

- The inclusion of virtual instructor: Learning outcomes and learning activities are achieved partly by the playing game and partly by the interacting with the



virtual instructor.

### **3.2.3.3.2. Non-immersive GTI modules**

The objective of virtual reality-based games is to provide the users with 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 the head mounting display, data gloves, and Oculus Rift. The virtual reality hardware provides the users a full virtual immersion as well as six degrees of freedom. The other form of virtual reality game is non-immersive. The non-immersive games also provide the users with 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 the game using desktop monitor, keyboard and mouse. The GTI modules can be converted into the immersive virtual environment using hardware like oculus rift. The virtual reality hardware is expensive. We cannot provide required hardware to all students in the classroom. So, we developed non-immersive GTI modules, which can be easily implemented in the class curriculum.

### **3.2.3.3.3. Deployment Diagram for GTI modules**

The WorldViz Vizard toolkit is selected as a development tool for our GTI module. Vizard is a virtual reality software toolkit, 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. Vizard builds a virtual world that can be deployed everywhere. A deployment diagram illustrating the deployment of GTI modules is given in Fig. 41. The GTI modules were implemented using the Vizard IDE on the developer's side, denoted as "Developer side." The source code for the Linked list module and Binary tree module are implemented in python. Python is used in Vizard as a programming language for its

concise statement and syntax. Python is significantly refreshing, and it has robust open source libraries and toolkits. The source codes are indicated as binary tree.py and linkedlist.py. We have generated executable files having the .exe extension from those two programs. Finally, these executable files can run as standalone programs on the user's side, denoted as "User\_side" in the fig.41. We can use the executable file on any platform/environment. There is no need for installation of Vizard on the user's computer.

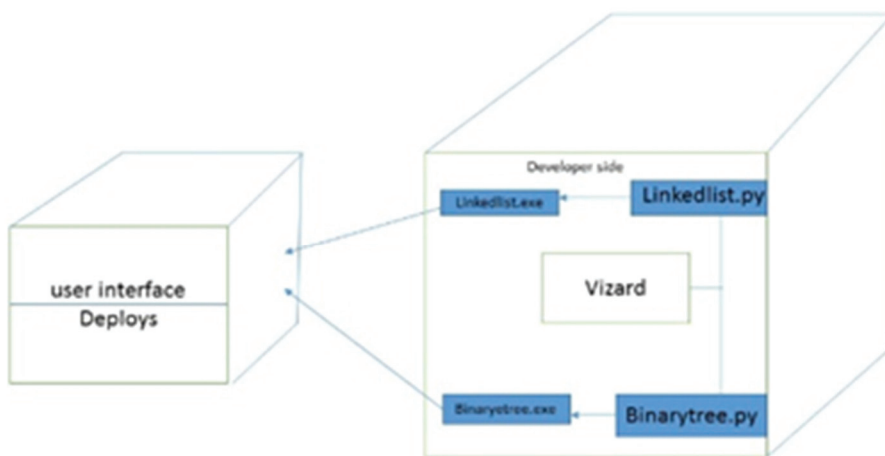


Fig. 41. The deployment diagram of GTI modules

### 3.2.4. Testing of GTI modules

Once the GTI modules were developed, we validated the GTI modules to confirm that the system meets the functional and non-functional requirements. We tested the GTI modules to teach binary trees and linked list in the virtual reality lab with my colleague working in the virtual reality lab who have exposure to virtual reality games. The pupils working in the lab have taken programming courses in the computer science department in either undergraduate or graduate level.

Testing objectives:

- To ensure that during operation the GTI modules to teach binary trees and linked list, will perform as per specification.
- To make sure that educational game based software meets our requirements during operation.
- To make sure that during the operation, when we feed incorrect input in the GTI modules, the processing and output should handle it appropriately.
- To observe that when correct inputs are fed to the GTI modules, the generated outputs are correct.
- To verify that the controls incorporated in the game theme-based instructional (GTI) modules work as intended.
- To design a good test case which has a high probability of finding an undiscovered error in the GTI modules.

We have tested that the instructions in the GTI modules appears clear and concise to the pupils in the virtual reality lab. We also tried to find the GTI modules are usable and likable. The whole system (GTI modules) was validated by my colleagues in the virtual reality lab and collected their opinion about the likability of educational software. The GTI modules were also tested if the pseudo codes of a binary tree and linked list were displayed on the screen while using the GTI modules. The technical problem related to the system such as (1) system crashes and (2) ability to restart the GTI modules, were also tested. The system is tested to confirm that there are virtually no technical difficulties when using the GTI modules. In other words, we want

to confirm the GTI modules are usable. We tested the GTI modules on a different platform to confirm that, the GTI modules should not depend on a particular platform. We also validated the GTI module's responsiveness to the users input. So, when the user presses a key from the keyboard or clicks the mouse during playing with GTI modules, they will get an immediate reaction. Successful testing is one that uncovers an undiscovered error in the software. The software (GTI modules) developed has been tested successfully using the following testing strategies. Any errors that are encountered during testing are corrected, and again the part of the software or the procedure is put to testing until all the errors are removed. The result of the system testing of GTI modules proves that the system is working correctly. It gives the confidence to the system designer, ends users of the GTI modules and, prevent frustration during the implementation process.

#### 3.2.4.1. **Black Box Testing**

We have used Black Box Testing for the validation of GTI modules. In this testing approach, we attempt to find errors in the following areas or categories:

1. Incorrect or missing functions.
2. Interface error.
3. Errors in data structures.
4. Performance error.
5. Initialization and termination error.

Here all the input data must match the instruction given in the GTI modules, to become a valid entry.

The following are the different tests at various levels of development of the GTI modules:

### 1. Unit Testing:

Unit testing was performed in the initial stage of development with the help of our colleagues in the virtual reality lab. This level of testing is essential for the verification of the python source code produced during the coding phase of GTI modules. The goal of unit testing is to test the internal logic of the learning module programming/source code. The unit testing was done during the coding phase of GTI modules. The functions of the GTI modules to teach binary trees and linked list were tested for correct operations. In this phase of testing, all the drivers are tested whether they are rightly connected or not.

### 2. Integration Testing:

All the tested modules (modules to teach a various aspect of binary trees or linked list) are combined into subsystems, which are then tested. The goal of the integration testing was to see if the modules were integrated correctly. The emphasis of the integration testing is on the testing interfaces between the various modules. In the GTI modules code integration testing was done mainly on three separate games of GTI module to teach binary trees and the three independent games to teach the various aspect of a linked list.

### 3. Validation Testing

We did validation testing to confirm that the educational software (GTI modules to teach binary tree and linked list) is error-free in all respects. All the specified validations are verified, and the educational game based software is subjected to hard-core testing. The validation testing of GTI modules also aims at determining the degree of deviation that exists in the software designed from the specification. We listed the degree of deviation and corrected the errors.

#### 4. System Testing

The last level of testing of GTI modules was system testing. System testing of GTI modules was a series of different tests whose primary function is to exercise the computer-based system fully. This level of testing involves:

- Implementing the GTI modules in a simulated production environment and testing it. We tested the software with the colleagues who have taken the programming course at either graduate or undergraduate level.
- Introducing errors and flaws in the GTI modules.
- Testing the GTI modules for error handling.

#### 3.2.4.2. TEST CASES

##### TEST CASE 1:

Test case for selecting and starting any game in the GTI modules:

When a user tries to select a game by clicking on the appropriate button, it displays a countdown message "GAME STARTS IN \_\_ SECONDS" and within 5 to 8 seconds the selected game will start.

##### TEST CASE 2:

Test case for playing a game:

When a user enters the answers, they will get an immediate response of either a rewarding message or a message to try again. The user was also able to see the instruction to proceed further.

### TEST CASE 3:

Test case for virtual Instructor:

When the users need any help, they can click on the help button located on the right-hand corner of the screen behind the 3D avatar of the virtual instructor. We tested the help button for proper functions. There are three kind of help such as: (1) how to proceed, (2) the concept related to the current game, (3) what will come next. There are three separate buttons for these three kinds of help. We tested each of these buttons functions.

### TEST CASE 4:

Test cases for switching from one game to another:

If the user no longer wants to continue a particular game, they can end the game by clicking on the end button located on the screen and can go back to the main menu section. We have tested the end button working correctly or not by clicking on end button in each game. If there was an error when it was listed and corrected.

### **3.2.5. Evaluation**

Finally, the software applications (GTI modules) are ready for deployment to a live environment (undergraduate and graduate classroom). The evaluation phase entails not just the evaluation of the application, but also subsequent support and maintenance.

Evaluation of GTI modules is done in two phase.

- 1) In the first phase, the GTI module was evaluated in summer semester with the interaction of undergraduate and graduate students to GTI modules. In the evaluation process, we demonstrated GTI modules to the students. All the students completed a post-survey.

Based on students reviews, the software applications (GTI modules) were updated to fulfill the users/students' requirement.

2) In the second phase of the evaluation process, the students were asked to complete pre-survey at the beginning of the semester (spring 2018). Then during the semester, we demonstrated the updated version of GTI modules and asked them to use the GTI modules. The students' needs little or no technical support while they use GTI modules. Then they were asked to complete a post survey. Both the pre-survey and post-survey based on widely used student evaluation survey. The GTI modules are evaluated using four widely proven methodology:

- Science Motivation Questionnaire II (SMQII)
- Student Assessment of Learning Gains (SALG) survey.
- User Engagement Scale (UES)
- Theory of Reasoned Action (TRA)

#### **3.2.5.1. Science Motivation Questionnaire II (SMQII) to evaluate motivation**

For evaluating the motivation of the students to learn binary tree and linked list concepts, we have used 'Science Motivation Questionnaire II (SMQII). SMQII assessed five motivation components:

1. Intrinsic motivation: Using SMQII we have evaluated the students were intrinsically motivated or not.
2. Self-determination: The students' self-determination component includes the students believe they have over their learning of linked list and binary tree concept.



3. Self-efficacy: The self-efficacy component, includes the students' belief that they can achieve well in binary trees and linked list concepts.
4. Career motivation: The career motivation component of SMQII involves the motivation to learn linked list and binary trees concepts using GTI modules and; think about career possibilities.
5. Grade motivation: Grade motivation is an extrinsic motivation which involves the motivation related to grade point average.

After collection of data, we had done statistical analysis using a t-test based on the hypothesis that students get motivated to learn linked list and binary trees when they used GTI modules.

### **3.2.5.2. Student Assessment of Learning Gains (SALG) survey to evaluate learning gain**

We have used the SALG survey to evaluate the degree to which GTI modules have enabled the students learning. We customize the SALG to reflect the learning activities and objectives of binary trees and linked list concepts and then conduct the assessment of GTI modules online using survey monkey website.

Student Assessment of Learning Gains (SALG) instrument has five potential questions, each of which were customized to evaluate the learning gain from GTI modules. These questions are:

1. How much did the interacting with GTI modules help the students in their learning?
2. What gains did the students make in their understanding of linked list and binary trees concepts using GTI modules?
3. What gains did the students make in the skills such as writing an algorithm involving the concepts of the linked list and binary tree when using GTI modules?

4. What gains did the students make in the INTEREST and ATTITUDES towards programming due to use of GTI modules?
5. Find the level of agreement to the experience so far in the programming class which includes: (1) Quality gaming experience with the GTI module based on the binary tree. (2) Quality gaming experience with the GTI module based on the linked list. (3) The difficulty of the GTI modules was appropriate for their level of skill and knowledge.

After collection of data, we performed statistical analysis using a t-test based on the hypothesis that there is learning gain when GTI modules are used to learn linked list and binary trees. We have also done a qualitative analysis of learning gain based on grounded theory.

### **3.2.5.3. Theory of Reasoned Action (TRA) to evaluate the likability**

We have evaluated the likability of GTI modules using TRA by defining a relationship between behavior, attitude, subjective norm and, self-efficacy. TRA is one of the most expensive research done in the history of social psychology. Several researches have been done to find the behavioral determinants such as likability of a product using TRA framework (refer chapter 2). When we try to assess the immediate response of behavior, we only need to assess the attitude, intention and subjective norm toward the specific behavior. Nguyen and Choudhury [105] 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. We have incorporated TRA to find the likability of GTI modules based on familiarity with other virtual reality games.

We have created a few questions in post-survey based on their attitudes (likability) towards GTI modules. Additionally, we have added a few questionnaires to find the familiarity of

students with virtual reality games. Then we have divided the students into three categories based on the familiarity of virtual reality games such as (1) expert, (2) intermediate and, (3) novice players. After collection of data, we have statistically evaluated the likability of GTI modules using ANOVA analysis.

### **3.2.5.3. User Engagement Scale (UES) to evaluate usability**

UES is a self-report measuring technique which consists of 31 items implied to measure the usability of the software. We have modified the wording of the UES items to fit in the GTI modules context. We have also excluded a few questions which were not applicable to our study. We created 28 questions for the evaluation of GTI modules based on UES. We have used a five-point Likert scale ranging from "Always" to "Never."

The user engagement scale has six dimension which includes:

1. Focused attention (FA)
2. Felt involvement (FI)
3. Novelty (NO)
4. Endurability(EN)
5. Aesthetics (AE)
6. Perceived usability (PUS)

We have performed a qualitative analysis of usability based on the grounded theory. We have corroborated the results from quantitative analysis to the outcomes of qualitative analysis and reached a conclusion.

### **3.2.6. Maintenance of GTI modules**

After testing the GTI modules in the virtual reality lab, we evaluated the GTI modules to teach binary trees in the undergraduate classrooms in summer 2017. There are some issues which come up in the actual user's environment (undergraduate and graduate classrooms).

We listed down the loopholes and flaws such as:

- (1) Clarity in the voice of instructor.
- (2) Visibility issues of pseudo code.
- (3) Users need more help while using GTI modules.

Patches were released and tested to fix these flaws. Also, we enhanced the GTI modules, and some better versions were developed. Maintenance of GTI module is done to deliver these changes in the user's environment.

We categorized the maintenance activities of GTI modules into four classes:

1. Adaptive: we modified the GTI modules to cope with changes in the software environment.
2. Perfective: we implemented new or changed users (undergraduate and graduate students of programming classes) requirements which concern functional or non-functional enhancements to the educational software.
3. Corrective: we diagnosed and fixed the errors, which were found by end users/students.
4. Preventive: we have increased the software maintainability to prevent all problems in the future.

## CHAPTER 4

### EVALUATION, RESULTS, AND DISCUSSIONS

#### 4.1. Introduction

The purpose of the research was to provide an exploratory foundation into the use of game theme based learning for undergraduate students of computer science department. Furthermore, in this research, we have used a proven framework with minor extension to evaluate the effectiveness of GTI modules. Besides, we have used the constructive learning approach and provided a detailed description of learning based on educational software games. The research described in this thesis is grounded in the field of computer education and game design. The following five research questions were based on the study's purpose and problem statement:

1. Is game theme-based instructional module capable of producing better learning outcomes?
2. Is game theme-based instructional module effective to motivate and actively engage students?
3. Is game theme-based instructional module effective in improving understanding of the concepts?
4. What are the main issues to consider to introduce the GTI module in the class curriculum?
5. Is game theme based learning usable and likable?

The previous chapters of this dissertation examined the purpose, problem statement, literature review, and methodology employed in the current research study. This chapter presents the evaluation, data analysis, and results. The GTI modules have been evaluated in two phases.

#### **4.1.1. Participants**

The participants of the study were selected from the computer science department of Bowie State University. GTI modules were evaluated with both the graduate and undergraduate students (Phase I: N=14, 8 undergraduate and 6 graduate students in summer 2017 and, Phase II: N=57, 42 undergraduate and 15 graduate students in fall 2018). All the students who participated in the evaluation process were enrolled in an introductory programming course. The selection of participants was gender agnostic, but the participants did have to indicate the gender (male/female) in the survey questionnaire. In a phase II user study, 36 students were male, and 21 students were female. The age of the participants (students) was between 18 years to 26 years. The participants may or may not have exposure to virtual reality games. The students were divided into three categories based on their level of familiarity to the virtual reality games. The categories included, (1) novice player of software games, (2) intermediate player of software games, (3) expert player of software games. Majority of the participants were full-time students, but the part-time students who were currently enrolled in an introductory programming course also participated in the evaluation process of GTI modules.

#### **4.1.2. Data collection procedure**

The instructor of the participated (introductory programming) classes received an e-mail invitation that included a small description of GTI modules, the process of the study, an introduction of the purpose of the study and, my contact information. In-person discussion was

also conducted with the instructor to take the permission for the evaluation of GTI modules and explain about the whole procedure of user study such as (1) time needed for user study, (2) the required technical resources and (3) topics (linked list and binary tree) which students are going to learn using GTI modules.

During the evaluation process, students were explained how to use the GTI module application. GTI (binary trees and linked list) modules were demonstrated to the students. All students completed a post-survey that included few questions enquiring about user's demographics which includes: student's gender, major and the name of programming courses they have taken or taking. Post-survey was a self-reporting questionnaire to evaluate the learning gain, motivation, usability and, likability of the GTI modules. The questions of post-survey were based on Student Assessment of Learning Gains (SALG) survey, Science Motivation Questionnaire II (SMQII), User Engagement Scale (UES) and Theory of Reasoned Action (TRA). There were several questions based on the familiarity of students with other virtual reality games. We have used a five-point Likert scale ranging from "Always" to "Never" (Appendices A and B). We have used Survey Monkey to analyze the results of the evaluation of GTI modulus into various downloadable formats.

#### **4.1.3. Institutional Review Board**

The user study was conducted in a respectful, ethical manner and followed all the guidelines of the Institutional Review Board (IRB). The IRB is a committee of people who inspect the proposals of the researchers and give the permission code to the researcher only if the user study supports the safety and rights of all human participants. The identities of all the participants have been kept confidential and anonymous. There was no participant's identifier number. Therefore, no one can identify which response is done by whom. Besides, no participants need any special

protection. The participants in the study are not expected to experience any direct benefit. However, they would learn introductory programming concepts such as linked list and binary tree. Participants will always be informed that they can opt out at any time during the user study. The consent procedures will be conducted in the same place where the user study will take place so that the research staff can show the participants how to use the GTI modules.

Their participation contributed to the knowledge that may be beneficial to them or other students of introductory programming courses. This user study had been approved by the Institutional Review Board (IRB Number 018-001).

#### **4.2. Evaluation of GTI modules**

Evaluation of GTI module was done in two phases. The first phase of the evaluation was done in summer 2017 (N=14 including 8 undergraduate students and 6 graduate students) to evaluate the effectiveness of GTI module to teach the concept of the binary tree. The GTI modules to teach linked list was in progress during the first phase of evaluation. So, the GTI module to teach linked list was evaluated in study two. In the first phase (study one), GTI module to teach binary tree was assessed (during early implementation) for following reasons (1) to evaluate the effectiveness of GTI modules and; (2) to gather information about how to revise and modify the GTI modules for improvement in the effectiveness of GTI modules. We have also collected the suggestion/comments from the users and tried to apply for the improvement of GTI modules. If the students do not have familiarity with virtual reality games, they may have the problem in navigating through the virtual world of GTI modules. Some students asked to add the concepts related to gameplay while they were playing. To resolve these issues (based on student's feedback), we have added a steady virtual instructor in the GTI modules to teach binary



trees and linked list. The virtual instructor helps the students during the gameplay (fig 30). The virtual instructor helps the students/users in three ways, which include:

- (1) The virtual instructor explains how to proceed in the gameplay.
- (2) The virtual instructor explicates the educational content related to gameplay.
- (3) The virtual instructor describes the topic to be discussed in the next screen.

Before adding the GTI modules in the regular class curricula, we wanted to evaluate that the GTI modules are motivating, usable, likable and produce appropriate learning gains (for learning of linked list and binary tree).

The second phase of the evaluation was done in spring 2018 (N=57) to evaluate the effectiveness of both GTI module (1) to teach binary tree, (2) to teach linked list. For finding the effectiveness of GTI modules, we have evaluated four aspects of GTI modules which includes (1) Learning gain from GTI module (2) motivation to learn binary tree and linked list using GTI modules, (3) likability of GTI modules and, (4) usability of GTI modules. Based on the feedback in the first phase, we have following improvements in the user study of the second phase.

1. Improvement in GTI modules: inclusion of virtual instructor in both binary tree and linked list module for helping the students during gameplay.
2. Improvements in the evaluation of the study: we have used formerly applied framework for the evaluation of GTI modules. In the phase II, we have used proven survey/scale such as (1) Student Assessment of Learning Gains (SALG) survey to evaluate the learning gain from GTI modules, (2) Science Motivation Questionnaire II (SMQII) for evaluating the motivation of students from the usage of GTI modules, (3) User Engagement Scale (UES) for evaluating the usability of GTI modules and,

(4) Theory of Reasoned Action (TRA) for evaluating the likability of GTI modules.

Table VIII. Summary of the methodology

Testing	Evaluation methodology used
Learning gain	T-test, Grounded theory
Motivation to learn	ANOVA test, T-test
Usability	Grounded theory
Likability	ANOVA test

For the evaluation of learning gain, we have done both qualitative and quantitative analysis. We have used a T-test for the quantitative analysis of learning gain. For the qualitative analysis, we have used "Grounded theory." We have also added a comment section in the post-survey. The comments were used for qualitative analysis of learning gain. The statistical analysis of motivation to learn the binary tree and the linked list was done using ANOVA test. For the evaluation of likability of GTI modules, we have used the statistical analysis based on the ANOVA test. The usability of any software is the most important aspect of evaluation. So, we have evaluated the usability of GTI modules both qualitatively and quantitatively. Then corroborate the quantitative results in the quantitative results of the usability of GTI modules.

### 4.3. Study one for evaluation of GTI modules

In the first phase of evaluation, the GTI modules were evaluated in summer 2017 semester by 8 undergraduate and 6 graduate students (N=14) of the Computer Science department.

### **4.3.1. Participants**

We have evaluated the game theme-based instructional module with the interaction of undergraduate and graduate students (summer semester N=14) to GTI modules. The survey data shows that 46.15% of students were female, and 55.85% of students were male. The survey data demonstrates that 42.66% students from computer technology, 50% students were computer science, and 7.14% of students were from the mathematics department. All students have taken before or currently taking a programming course. 28.57% from COSC-504 course 57.14% students from COSC-113 course, and 14.29% from COSC-561 course.

### **4.3.2. Data collection**

We have asked the instructors of introductory programming courses for the evaluation of GTI modules in their classroom. We have explained the study procedure and time needed to complete the user study. After getting the permission from the instructor, we have evaluated the GTI modules in the introductory programming classes. In the evaluation process, we demonstrated GTI modules to the students. We explained to them the study procedure and how to use the GTI module application. During the session, the participants used the GTI modules on desktop computers. The participants can either install the application (GTI modules) on their laptops or use the university desktops for the study. Students were asked to play with GTI module for 10 to 15 min. After interaction with GTI modules, the participants were asked to complete a post-survey. In the post-survey, the first few questions contained the inquiry to find user's demographics which includes: student's gender, major and the name of programming courses they have taken or taking. The whole procedure of user study took 25 to 30 min. We have included a comment section for improvement and modification in GTI modules.

### 4.3.3. Data analysis

The survey data demonstrates that the binary trees (GTI) modules make a significant educational influence on the students. According to survey data (fig.42), 38.46% of students strongly agree that the GTI module is motivating and 61.54% of students agree that GTI module is motivating. The error bar on bar graphs shows the motivation to learn a binary tree with a 95% confidence level. The statistical data of the post-survey shows that the GTI modules motivate almost 100% of students.

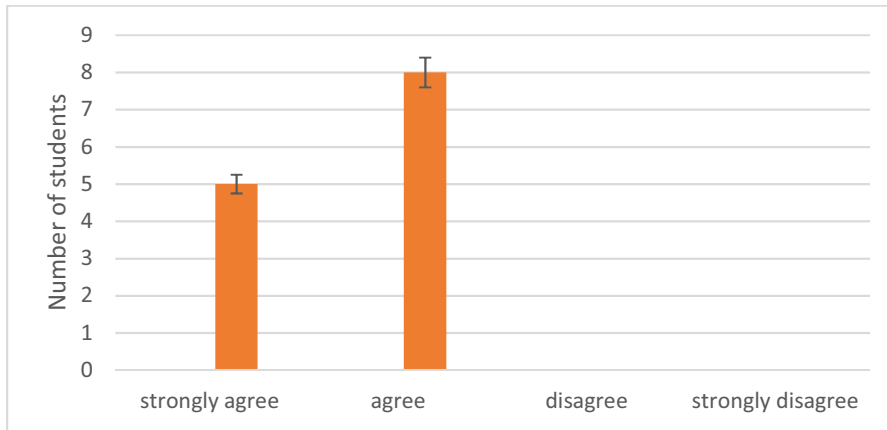


Fig. 42. Is the GTI module of binary tree motivating?

The survey data shows that the GTI modules make a noteworthy educational impact on the learners. The results of the evaluation show that the GTI modules ran well and met the requirement outlined in the design and interest of students in learning the concepts of binary trees structure is increased. As shown in fig. 43, 64.29% of students strongly agree that they understand the code while playing GTI modules of the 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. The error bar on bar graphs shows

that the students understand the code while playing GTI modules of a binary tree with 95% confidence level. Thus, the majority of the students learned various concepts related to the binary tree after using the GTI modules.

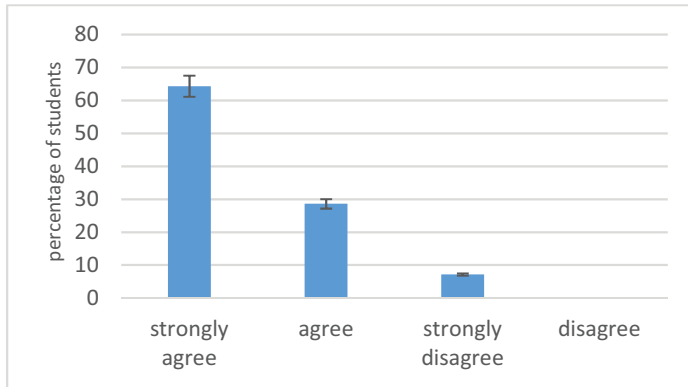


Fig. 43. Were you able to understand the code while playing GTI modules of a binary tree?

We have used virtual reality gaming metaphor for the development of GTI modules to make them more appealing to the students. However, we tried to keep its education contents as preeminent over other factors. The survey data shows that 76.92% of students strongly agree that the GTI module is education and 23.08% of students agree that GTI module is educational. As shown in fig.44, the more significant part of students thought that GTI module was educational. The error bar on bar graphs shows the GTI module of a binary tree is educational with 95% confidence level. Another question in the survey was, "did you get distracted from the main purpose of GTI modules while navigating through the GTI module?". Survey data reveals that most of the students think that they were not distracted from the main point while navigating through the GTI modules.

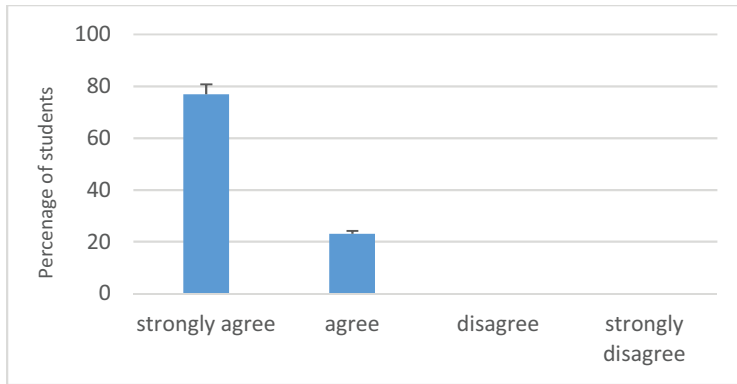


Fig. 44. Are GTI modules for binary tree educational?

We also tried to find the likability of GTI modules during the evaluation process. The survey data shows that 42.86% of students think that the GTI module is exciting and 28.57% of students think that GTI module is somewhat interesting. As shown in fig.45, the majority of students thought that GTI module was interesting (or likable). The error bar on bar graphs shows the GTI module is likable with 95% confidence level. GTI modules of binary tree educational So, we can infer that the GTI modules are likable.

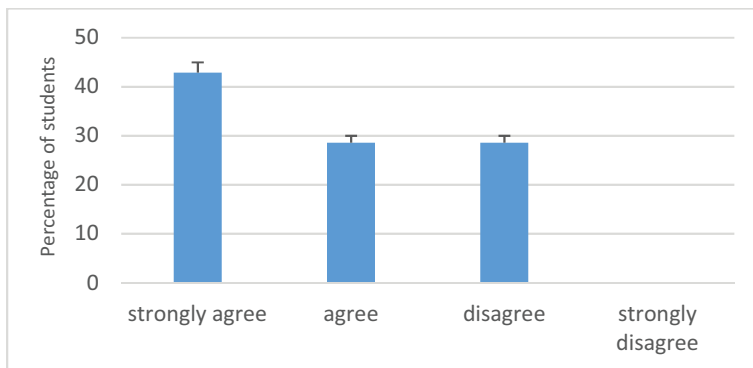


Fig. 45. What do you think about GTI modules of a binary tree (is it interesting)?

The post-survey also contained questions about the usability of GTI modules. One of the questions in the survey, "did you face any technical difficulty while navigating through the GTI module (fig. 46.)?", Was asked regarding finding the usability of the GTI module. According to

survey data, a substantial percentage of students (87.86%) didn't face any technical difficulty in navigating through the GTI module. So, we can conclude that the GTI module was usable.

Further evaluation was conducted for usability and likability of the GTI modules in phase II.

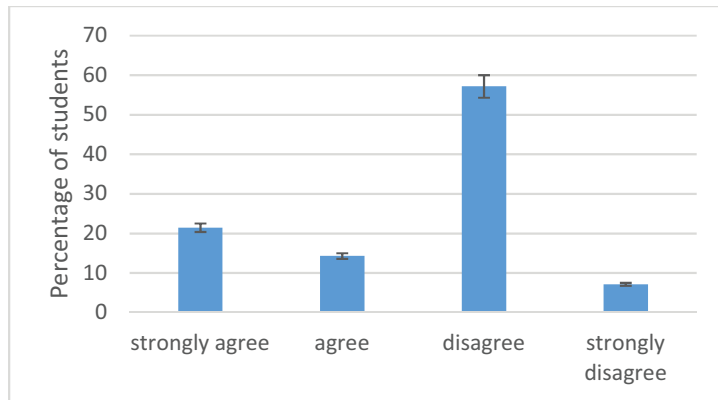


Fig. 46. Did you face any technical difficulty while navigating through the GTI module?

For, qualitative analysis of GTI modules we have included a text box (comment section) at the end of the post-survey. Additionally, we also noted the suggestion of the participants/students during the evaluation process. Based on students reviews the software applications (GTI modules) were updated to fulfill the users'/students' requirement. The post-survey data of study one shows that the GTI module motivates the students to learn and enhanced learning outcomes. The results of the survey demonstrate that GTI module is usable and likable by all students. The qualitative observational data shows that the GTI module when implemented in VR environment as an instructional aid affected and deepened learning outcomes with the unique benefit of an engaging platform sustaining students' creativity in problem-solving. Based on student's feedback, we developed another GTI modules to teach linked list. We have added a steady virtual instructor in the GTI modules to teach binary trees and linked list. The virtual instructor helps the students during the gameplay.

#### **4.4. Study two for evaluation of GTI modules**

In the second phase of the evaluation process, the students were asked to complete pre-survey at the beginning of the semester (spring 2018). Then during the semester, we demonstrated an updated version of GTI modules to the students. We explained to them the study procedure and how to use the GTI module application. The students have required little or no technical support while they use GTI modules. Then they were asked to complete a post-survey. Both the pre-survey and post-survey based on widely used student evaluation survey. The evaluation and data analysis were straightforward and correlational and the statistical analysis program used in the study was based on two proven methods of evaluation, which includes: (1) Science Motivation Questionnaire II (SMQII), (2) Student Assessment of Learning Gains (SALG) survey.

##### **4.4.1. Participants**

For the final study, we have conducted both pre-and post-survey in the spring semester in the computer science department. The pre-survey was done at the beginning of the semester with 32 students (20 undergraduate students and 12 graduate students) in the introductory programming classes. Before the semester reaches to the end, we have conducted a user study (post-survey) in the same introductory programming classes with 15 graduate and 42 undergraduate students (N=57). All participants were currently enrolled in the introductory programming classes. The students needed minimal technical support during the evaluation of GTI modules. In a final user study, 36 students were male, and 21 students were female. We divided the participants into three categories (expert, intermediate and novice user) based on the familiarity of the students with the software games.

##### **4.4.2. Data collection**



After getting the permission from the instructor of the participated (introductory programming) classes, we have evaluated the GTI modules with graduate and undergraduate students. 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 module. Then the students played with the GTI modules for 10 to 15 min. After the gameplay in GTI modules, the students were asked to complete the post-survey. The study lasted for approximately 25-30 min. Both pre- and post-survey questionnaire were based on proven survey named Student Assessment of Learning Gains (SALG) survey, Science Motivation Questionnaire II (SMQII), User Engagement Scale (UES) and Theory of Reasoned Action (TRA). We have used a five-point Likert scale ranging from "Always" to "Never." We have used the Survey monkey engine web application for pre-and post-survey for the evaluation of GTI modules. We have downloaded the collected data from the Survey Monkey website in a different format for the statistical analysis of learning gain, motivation, usability, and likability of GTI modules. In the post-survey, few questions are about the participants' demographics such as gender, race, enrollment status and the name of programming courses they have taken or taking.

#### **4.4.3. Data analysis**

In the post-survey, few questions are about the participants' demographics such as gender, race, enrollment status and significant. The survey data shows 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. The questions of post-survey were based on four proven evaluation methodology which includes:

1. Student Assessment of Learning Gains (SALG) survey to evaluate the learning gain from GTI modules.
2. Science Motivation Questionnaire II (SMQII) for evaluating the motivation of students from the usage of GTI modules.
3. User Engagement Scale (UES) for evaluating the usability of GTI modules.
4. Theory of Reasoned Action (TRA) for evaluating the likability of GTI modules.

#### **4.4.4. Evaluation of Learning gain using the Student Assessment of Learning Gains survey**

The SALG instrument focuses exclusively on the degree to which GTI modules have enabled student learning. The SALG asks pupils to assess on their learning. Then the students report the degree to which GTI modules have contributed to that learning. We customize the SALG to reflect the learning activities and objectives of co-programming language courses, and then administer the assessment of the students online using survey monkey website.

Student Assessment of Learning Gains (SALG) instrument has five underlying questions, each of which we have customized to learn programming concepts. These questions are:

1. How much did the interacting with GTI modules help you in your learning?
2. As a result of using GTI modules in this class, what gains did you make in your understanding of each of the following?
  - The linked list concepts explored in the GTI modules.
  - The binary tree concepts explored in this GTI modules.
  - Understanding of inorder, preorder and postorder traversal of binary tree.
  - Understanding of doubly linked list and circular linked list.

3. As a result of your work in this class, what gains did you make in the following skills?
- Write an algorithm involving the functions of the linked list.
  - Write an algorithm involving the functions of the doubly linked list.
  - Write an algorithm involving the functions of a binary tree.
4. As a result of your work in this class, what gains did you make in the INTEREST and ATTITUDES of each of the following?
- Enthusiasm for the computer science.
  - Enthusiasm for the programming.
  - Interest in computer science.
  - Interest in discussing learning with friends and family.
  - Confidence that I understand the material
  - Confidence that I can do computer science
5. Please rate your level of agreement to the following experience so far in the programming class.
- I had quality gaming experience with the GTI module based on the binary tree.
  - I had quality gaming experience with the GTI module based on the linked list.
  - The difficulty of the GTI modules was appropriate for my level of skill and knowledge.

#### 4.4.4.1. Qualitative analysis for evaluation using Grounded theory

For qualitative analysis of learning gain from the usage of GTI modules, we have included three text boxes in the post-survey. The comment section (Text boxes) were used for collecting the voice of the students. As the students are the end-user of GTI modules, the voice of students is vital for us. In these textboxes, the students were asked to write their opinion about the GTI modules which includes:

1. Please comment on “How your understanding of the subject has changed” because of using GTI modules (binary tree and linked list) in this class.
2. Please comment on how the GTI modules to teach binary tree and linked list help you remember the key ideas of the content.
3. Please comment on how class activities (gameplay in GTI modules) helped your learning.

The qualitative analysis of GTI modules to evaluate learning gain was based on the "Grounded theory." The grounded theory is a sociological approach that discovers the theories from the data and; not based on any pre-determined theoretical framework. The grounded theory is based on the concept of abduction which is a combination of induction and deduction. The students were free to add their voice in the comment section (text boxes) either positive or negative based on their experience with the GTI modules. We have collected the data (induction) from the comment section (text boxes), then the data were empirically evaluated (deduction) to reach a conclusion. The student's actual comments and their analysis is shown in table IX, X and, XI.

Table IX. Users comments and analysis of how the understanding of the subject has changed after usage of GTI modules

serial #	Comments	Analysis
1	didn't have enough time to use the modules but it was quite straight-forward and engaging.	Positive
2	I had a good understanding of the program.	Positive
3	I still don't understand	Negative
4	I know more about binary trees.	Positive
5	I understood a lot better because o-f the preparation the subject has taught me	Positive
6	It has helped me changed because I know a little more of the linked list.	Positive
7	It was a great experience.	Positive
8	Changed dramatically	Positive
9	It helped break it down.	Positive
10	It hasn't really changed, but it helps us understand the topic even more.	Positive
11	Visuals and metaphors prove as effective learning tools	Positive
12	My class has yet to reach the topic of binary trees, but the app helped introduce the topic.	Positive
13	it gives an insight of virtual technologies could be used to simplify problems	Positive
14	Good	Positive
15	somewhat improved	Positive
16	Helped me get a visual understanding of Binary tree	Positive
17	So far so good	Positive
18	great outcome	Positive
19	It was helpful seeing a demonstration with the code	Positive
20	very well.	Positive
21	GOOD	Positive
22	My knowledge was heightened due to the visuals utilized in the game which helps me understand better.	Positive
23	More pictures help me understand	Positive
24	It has helped a lot	Positive
25	I learned the difference between singly and doubly linked list.	Positive
26	The way it showed how each program would work in real life	Positive
27	Nodes became more understandable	Positive
28	My understanding did not change.	Negative
29	has not changed	Negative
30	i learned double linked lists	Positive
31	it helped	Positive
32	My understanding of the subject has increased	Positive

Table X. Users comment and analysis of how the GTI modules to teach binary tree and linked list help you remember the key ideas of the content.

serial #	Comment	Analysis
1	by building the links right there helps to remember the concept.	Positive
2	it helps me by showing me the code.	Positive
3	I'm a biology major	neither positive nor negative
4	it helps remember key ideas by it being a game catching my attention.	Positive
5	I believe the GTI models helped me remember a lot	Positive
6	moderately effective	neither positive nor negative
7	It was a great experience.	Positive
8	The visuals (while not attractive) did provide for an easier method of remembering the concepts.	Positive
9	Linked list and binary trees became clearer topics for me	Positive
10	It had repetition.	Negative
11	It shows how it is similar to a real object.	Positive
12	The metaphorical comparisons are a big help	Positive
13	Good	Positive
14	somewhat helped	Positive
15	So far so good	Positive
16	not at this time	Negative
17	the visual effects helped me	
18	made so easy.	Positive
19	help you to visualize the real situation	Positive
20	very clear	Positive
21	Real world examples	Positive
22	The visuals helped me remember it	Positive
23	It helped me to visual the concept.	Positive
24	The way it was formatted	neither positive nor negative
25	The games give real world examples	Positive
26	n/a	neither positive nor negative
27	it didn't	Negative
28	connects ideas to relatable things	Positive
29	They are repeatable, which helps me remember the concepts	Positive

Table XI. Users comment how class activities (gameplay in GTI modules) helped your learning.

serial #	Comment	Analysis
1	helped to see where I'm at in the class and how to improve.	Positive
2	N/A	neither positive nor negative
3	It would be hard for me to learn when i get home	Negative
4	the lectures and program assignments helped a lot	neither positive nor negative
5	Class Activities has helped me learn and practice more.	Positive
6	It was a great experience.	Positive
7	Helped a lot	Positive
8	It doesn't help.	Negative
9	It gives hands-on time so it won't just leave out my other ear.	Positive
10	Good	Positive
11	practice helped a lot	Positive
12	visual learning is key	Positive
13	Greatly	Positive
14	Hands on help	Positive
15	it was a different type of learning	Positive
16	By understanding what I already know it made it much simpler to understand	Positive
17	Applying what I know helped to understand what i was trying to accomplish.	Positive
18	examples helped	Positive
19	it does	Positive
20	labs help me learn the concepts	neither positive nor negative
21	Keeping me engaged helped strengthened my knowledge of C++ programming	Positive

Table XII. Qualitative analysis of learning gains from the usage of GTI modules

Text box or comment #	Positive comments	Negative comments	Neither positive nor negative
Question 1	90.625%	9.375%	0
Question 2	75.86%	10.34%	13.79%
Question 3	76.19%	9.52%	14.29%
<b>Average=</b>	80.89%	9.75%	9.36%

From the table XII, we can infer that 90.625% positive comments for the first question, whereas only 9.375% comments were negative. We can also see that for the question "How the GTI modules to teach binary tree and linked list help you remember the key ideas of the content?", 75.86% is positive, and 10.34% are negative. Additionally, we can observe that for the third question, 76.19% are positive and 9.52% are negative. So, we can draw a conclusion qualitatively that GTI modules produce better learning gain.

#### 4.4.4.2. Quantitative analysis using T-test

After collecting the data from all participating classes of introductory programming courses, we have analyzed the data using the T-test for evaluating the learning gain. We have used a five-point Likert scale ranging from "strongly agree" to "strongly disagree." Table XIII shows the mean value of learning gain of students (for both the pre- and post-survey) in different aspects of learning of binary tree and linked list concepts. We have analyzed the collected data (table XIV) using T-test with the hypothesis:

- $H_1$ : There is a significant difference between the learning gain of students when they use GTI module to learn binary tree and a linked list.

We have tested our hypothesis is true using the null hypothesis  $H_0$ .

- $H_0$ : There is no significant difference between the learning gain of students in pre-and post-survey.

Table XIII. Mean values of learning gain in pre-and post-survey

LEARNING GAIN	pre-Survey	Post-survey
The main concepts explored in this class	2.06	3.86
The relationships between the main concepts	1.94	3.82
The linked list concepts explored in the GTI modules.	1.84	3.86



The binary tree concepts explored in this GTI modules	1.81	3.86
understanding of inorder, preorder and postorder traversal of the binary tree	1.94	3.79
understanding of doubly linked list and circular linked list.	2.13	3.87
How ideas from this class relate to ideas encountered in other classes within this subject area	2.19	3.98
How ideas from this class relate to ideas in classes outside of this subject area.	2.16	3.95
Attending lectures	2.94	3.89
Participating in discussions during class	3.09	4.07
listening to discussions during class	3.22	3.98
Using the GTI modules	2.10	3.85
working with the classmates	3.00	3.87
write an algorithm involving the functions of a linked list.	1.97	3.85
write a program involving the functions of a linked list.	2.03	3.87
write an algorithm involving the functions of a linked list.	2.03	3.89
traversing of the binary tree.	1.94	3.75
write an algorithm involving the functions of the binary tree.	1.88	3.89
Work efficiently with others.	2.16	3.82
Asking questions in class	2.22	3.93
Answering questions in class	2.16	3.96
Enthusiasm for the computer science.	2.47	3.82
Enthusiasm for the programming.	2.44	3.79
interest in computer science.	2.39	3.85
Interest in discussing game-based learning with friends and family.	2.28	3.77
Interest in discussing linked list or binary trees with peers.	2.23	3.75
Interest in taking or planning to take additional classes in computer science.	2.38	3.82
Interest in taking or planning to take additional classes in programming.	2.25	3.75
Confidence that I understand the material	2.50	3.91
Confidence that I can do computer science	2.38	3.91
Willing to seek help from others (e.g., teachers, peers, TA) when working on problem and assignments.	2.66	3.88
I am in this class because I like computer science.	3.83	3.67
I came to this class well prepared.	3.48	3.63
I have experience in computer programming.	3.34	3.24
I expected this class to be difficult.	3.82	3.98
This class is difficult.	3.59	3.83
I spend 2-5 hours each week on this course outside of class time.	3.48	3.79
I had quality gaming experience with the GTI module based on the binary tree.	2.76	3.33
I had quality gaming experience with the GTI module based on the linked list.	2.83	3.32
The difficulty of the GTI modules was appropriate for my level of skill and knowledge.	2.86	3.54
The difficulty of the GTI modules was appropriate for advancing my level of skill and knowledge.	2.97	3.49
I wrote the algorithm before using the GTI modules.	2.83	3.25
The GTI modules increased my level of interest in the course.	2.86	3.47

my interest in computing is based on programming.	3.59	3.40
my interest in computing is based on gaming.	2.93	3.18
I plan to get a career in technology.	4.03	3.65
I plan to get a career in computer science.	3.93	3.33

The result of the above t-test for learning gain is summarized in Table XIV. A total number of items which we need to compare using T-test were 47. Table XIV illustrates the mean values of the learning gain in for each of the groups (pre-and post-survey). The mean value of learning gain in post-survey was 3.74 whereas the mean value of learning gain in pre-survey was 2.63.

Table XIV. Results of T-test for learning gain

t-Test: Paired Two Sample for Means		
	Variable1 (Post-survey)	Variable2 Pre-Survey
Mean	3.743384	2.635572
Variance	0.051506	0.403491
Observations	47	47
Pearson Correlation	-0.40951	
Hypothesized Mean Difference	0	
Df	46	
t Stat	10.03258	
P(T<=t) one-tail	1.83E-13	
t Critical one-tail	1.67866	
P(T<=t) two-tail	3.67E-13	
t Critical two-tail	2.012896	

Additionally, it includes the respective results of the variances of both pre- and post-survey based on learning gain. The result involves the degree of freedom, the T values and the critical value of the t-tests. Results show that the degree of freedom (df) for the t-test is 46, t-value (t Stat) is 10.03258, and the critical value (t Critical two-tail) is 2.012896. The results of the t-test for the learning gain have shown that t-value (10.03258) is higher than the critical value

(2.012896). Additionally, the p-value (3.67E-13) of the t-test is lesser than the hypothesized p-value (0.05). So, we can reject the null hypothesis and; we will accept the alternate hypothesis such that there is a significant difference in learning gain when we use GTI module for learning binary trees and linked list.

#### **4.4.5. Evaluation of motivation using Science Motivation Questionnaire II**

To better understand what the students/users think about the educational tool (GTI module) and how they feel about their programming (computer science) courses, we have used 'Science Motivation Questionnaire II (SMQII). With the perspective of social cognitive theory, the motivation of computer science students to learn a programming language is examined. SMQII assessed five motivation components:

1. Intrinsic motivation: Using SMQII we tried to find where the students were intrinsically motivated or not.
2. Self-determination: The pupils' self-determination component includes the students believe they have over their learning of science (programming). Self-determination dimension includes questions such as I put enough effort into; I spend much time, I study hard to learn, I use strategies to learn, etc. The pupils thought of these questions (I spend much time, I study hard to learn, etc.) as unified.
3. Self-efficacy: The self-efficacy component includes the students' faith that they can achieve well in (programming) science. Self- efficacy dimension includes questions such as I am confident I will do well, I believe I can master; I believe I can earn a grade of "A," I am sure I can understand, etc. This component also involves assessment anxiety (e.g., I worry about getting a low grade in tests). If the self-efficacy is low, then it leads to high anxiety. We tested self-efficacy using revised

SMQ II and didn't include any question based on negative motivation based on anxiety.

4. Career motivation: The career motivation component involves the motivation to learn to write a program in their courses and think about career possibilities. This dimension includes questions such as it will help me get a good job, knowing programming will give me a career advantage, understanding programming will benefit me in my career, my career will involve science, etc. Career motivation is essential for the longtime goal and considered as the primary reason to get the college education. So, we have evaluated career motivation to learn to program.
5. Grade motivation: The grade motivation component involves the motivation related to grade point average. Grade motivation is an extrinsic motivation that includes questions such as I like to do better than other students, getting a good science grade is essential to me, it is vital that I get an "A" in programming, I think about the grade I will get in science, etc. Grades motivation is vital for short-term goals as grades are measures of student's success in college and part of the entry criteria for many professions.

#### **4.4.5.1. Statistical analysis of motivation using ANOVA test**

One of the goals of this research is to provide a better learning environment by increasing the motivation of the students toward learning. For the quantitative analysis of the data collected from the user study, we divided the student's data into three categories (expert, intermediate and novice user) based on the familiarity of the students with the software games. We randomly took 16 students from each category of students for ANOVA analysis. We did an ANOVA analysis of

the data for the three categories of students. We have done ANOVA test for all the five types of motivation individually.

1) We did the ANOVA test for “Intrinsic Motivation” of the students after interaction with GTI modules based on the hypothesis (H2).

- H2: the students had more exposure to other virtual reality games are more intrinsically motivated after interacting with GTI modules.

The results of the ANOVA test show that the difference was statistically not significant ( $p = 0.08 > 0.05$ ). So, the results do not support our hypothesis, which greater familiarity with software games results in more intrinsic motivation. The graph (fig. 47) shows that the mean value for all the three categories of student’s ranges from 60.3% to 78.75%. The error bar on bar graphs shows the intrinsic motivation with 95% confidence level. So, most of the students (mean value 66.88%) got intrinsically motivated toward learning when they use GTI modules for learning.

Table XV. ANOVA analysis of Intrinsic motivation

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Novice	16	48.25	3.015625	1.66224		
Intermediate	16	49.25	3.078125	2.039323		
Expert	16	63	3.9375	1.229167		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.492188	2	4.246094	2.583448	0.086675	3.204317
Within Groups	73.96094	45	1.643576			
Total	82.45313	47				

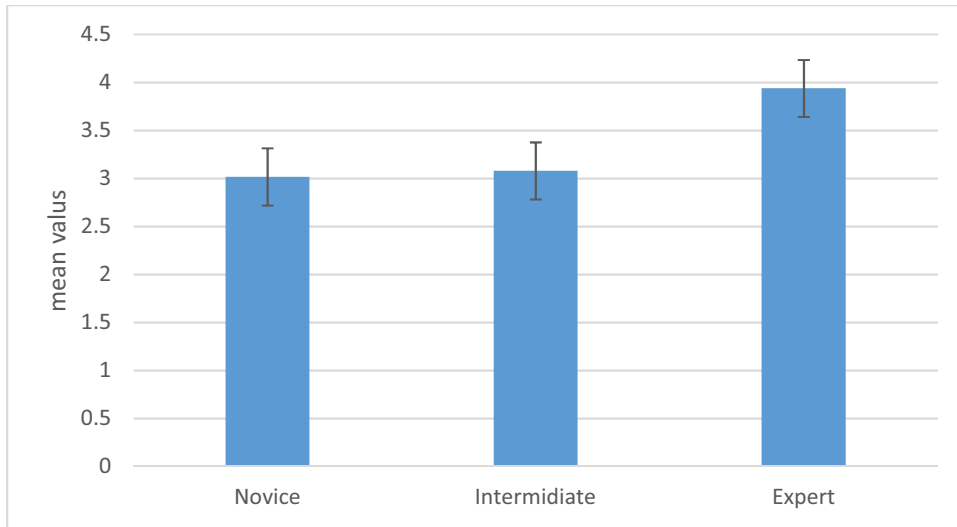


Fig. 47. Mean value of Intrinsic motivation for the three categories.

2) We performed the ANOVA test for “self-efficacy” of the students after interaction with GTI modules based on the hypothesis.

- H3: the students had more exposure to other virtual reality games have more self-efficacy than the students having less exposure to VR games, after interacting with GTI modules.

Table XVI. ANOVA analysis of self-efficacy

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Novice	16	49.75	3.109375	1.691406		
Intermediate	16	52	3.25	1.525		
Expert	16	67.75	4.234375	1.26224		
ANOVA						
Source of Variance	SS	df	MS	F	P-value	F crit
Between Groups	12.02344	2	6.011719	4.026922	0.024612	3.204317
Within Groups	67.17969	45	1.492882			
Total	79.20313	47				

The results of the ANOVA test show that the difference was statistically significant ( $p = 0.02 < 0.05$ ). So, the results support our hypothesis, which greater familiarity with software games results in more self-efficacy.

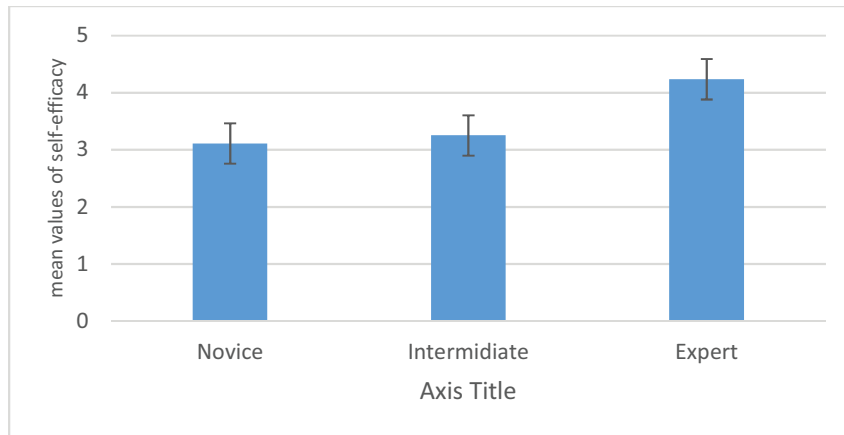


Fig. 48. Mean value of self-efficacy for the three categories.

The graph (fig. 48) shows that the mean value for all the three categories of student's ranges from 62.19% to 84.69% (fig. 48). The error bar on bar graphs shows the mean values self-efficacy with 95% confidence level. So, most of the students (mean value 70.64%) have improved self-efficacy toward learning when they use GTI modules for learning.

3) We did the ANOVA test for "self-determination" of the students after interaction with GTI modules based on the following hypothesis.

- H4: the students had more exposure to other virtual reality games have more self-determination after interacting with GTI modules.

Table XVII. ANOVA analysis for self-determination

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Novice	15	45	3	1.508929		
Intermediate	16	49.75	3.109375	1.341406		
Expert	15	59.75	3.983333	1.932738		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.777095	2	4.388547	2.762742	0.074339	3.21448
Within Groups	68.30443	43	1.588475			
Total	77.08152	45				

The results of the ANOVA test show that the difference was statistically not significant ( $p = 0.07 > 0.05$ ). So, the results do not support our hypothesis, which greater familiarity with software games results in more self-determination.

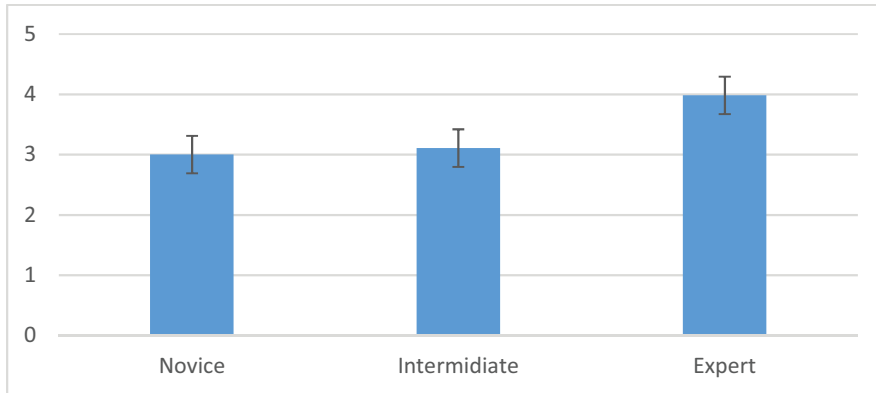


Fig. 49. Mean value of self-determination for the three categories.



The graph (fig. 49) shows that the mean value for all the three categories of student's ranges from 60% to 79.6%. So, most of the students (mean value 67.29%) got self-determination toward learning when they use GTI modules for learning.

4) We did the ANOVA test for "Grade Motivation" of the students after interaction with GTI modules based on the hypothesis.

- H5: the students had more exposure to other virtual reality games have more "Grade motivation" after interacting with GTI modules.

Table XVIII. ANOVA analysis for Grade motivation

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Novice	16	68	4.25	1.207407		
Intermediate	16	65	4.0625	1.277315		
Expert	16	69.33333	4.333333	1.185185		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.615741	2	0.30787	0.251672	0.778587	3.204317
Within Groups	55.04861	45	1.223302			
Total	55.66435	47				

The results of the ANOVA test show that the difference was statistically not significant ( $p = 0.7 > 0.05$ ). So, the results do not support our hypothesis, which greater familiarity with software games results in more grade motivation.

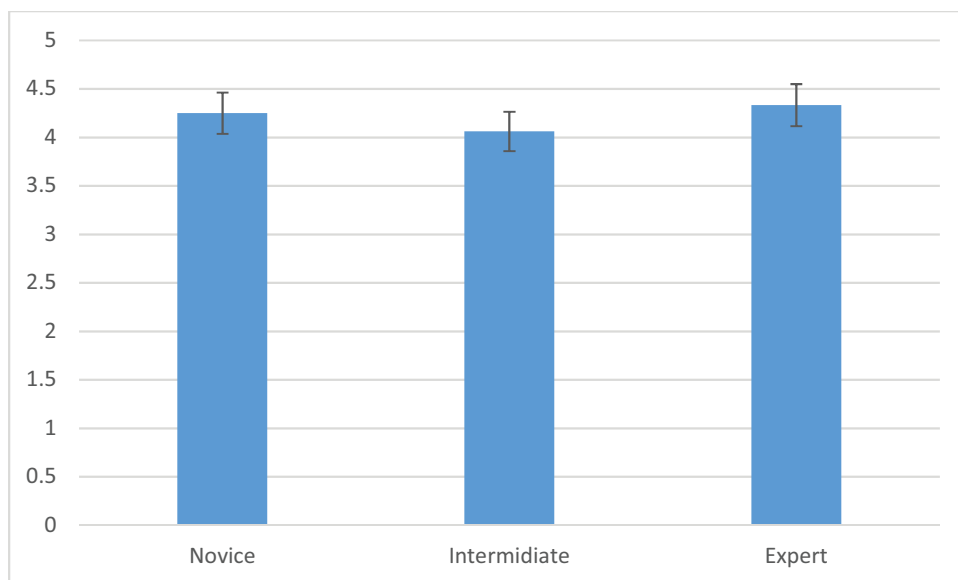


Fig. 50. Mean value of grade motivation for the three categories.

The graph (fig. 50) shows that the mean value for all the three categories of student's ranges from 81.25% to 86.67%. The error bar on bar graphs shows the grade motivation with a 95% confidence level. So, most of the students (mean value 84.3%) got grade motivation toward learning when they use GTI modules for learning.

5) We did the ANOVA test for "Career Motivation" of the students after interaction with GTI modules based on the following hypothesis.

- H6: the students had more exposure to other virtual reality games have more Career motivation after interacting with GTI modules.

The results of the ANOVA test show that the difference was statistically not significant ( $p = 0.9 > 0.05$ ). So, the results do not support our hypothesis, which greater familiarity with software games results in more Career motivation.

Table XIX. ANOVA analysis for Career motivation

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Novice	16	59	3.6875	2.495833		
Intermediate	16	62	3.875	1.483333		
Expert	16	60.5	3.78125	1.765625		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.28125	2	0.140625	0.073436	0.929307	3.204317
Within Groups	86.17188	45	1.914931			
Total	86.45313	47				

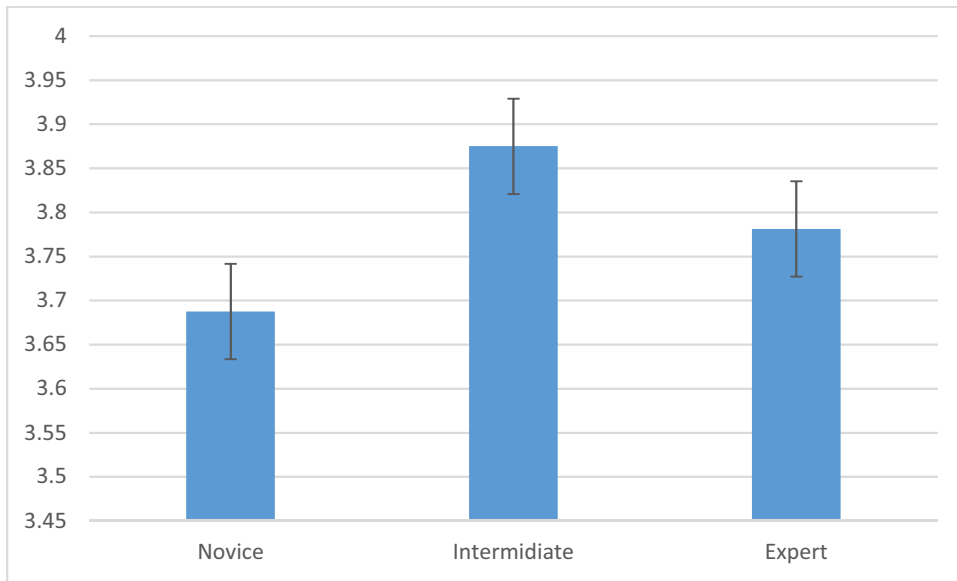


Fig. 51. Mean value of Career motivation for the three categories.

The graph (fig. 51) shows that the mean value for all the three categories of student's ranges from 73.75% to 77.5%. The error bar on bar graphs shows the career motivation with a 95%

confidence level. So, most of the students (mean value 75.63%) got Career motivation toward learning when they use GTI modules for learning.

#### 4.4.5.2. Statistical analysis of motivation using T-test

For the statistical analysis of motivation towards learning (the concepts of a binary tree and linked list) with the GTI modules, we have integrated the T-test. We have collected the data using pre- and post-survey from introductory programming classes (section 4.3.2 and 4.4.2)). We compare the data collected from pre-and post-survey using t-test. We have used a five-point Likert scale ranging from "strongly agree" to "strongly disagree." Table XX shows the mean value of motivation of students (for both the pre- and post-survey) in learning of binary tree and linked list concepts. We have analyzed the collected data (table XXI) using. T-test with the hypothesis:

- H<sub>7</sub>: There is a significant difference between the motivation of students when they use GTI module to learn binary tree and a linked list.

We have tested our hypothesis is true using the null hypothesis H<sub>0</sub>.

- H<sub>0</sub>: There is no significant difference between the motivation of students in pre-and post-survey.

Table XX. Mean value of motivation to learn in pre-and post-survey

Motivation	pre-survey	post-survey
The Linked list and binary tree concept I learn is relevant to my life.	2.65	3.40
Learning Linked list and binary tree concept is interesting.	2.61	3.59
I am curious about applications of the Linked list and binary tree concept.	2.39	3.55
I enjoy learning Linked list and binary tree concept.	2.58	3.51
I am confident I will do well on the Linked list and binary tree concept tests.	2.52	3.63
I am confident I will do well on labs and projects based on the Linked list and binary tree concept.	2.42	3.56

I believe I can master knowledge and skills based on the Linked list and binary tree concept.	2.19	3.69
I am sure I can understand Linked list and binary tree concept.	2.10	3.63
I use strategies to learn Linked list and binary tree concept well.	2.45	3.46
I spend much time learning Linked list and binary tree concept.	2.58	3.41
I prepare well for Linked list and binary tree concept tests and labs.	2.55	3.41
I study hard to learn Linked list and binary tree concept.	2.35	3.44
Getting a good grade is important to me.	1.43	4.28
I think about the grade I will get.	1.57	4.22
Scoring high on tests and labs matters to me.	1.37	4.31
Knowing the concepts in depth will give me a career advantage.	1.73	3.85
I will use the problem-solving skills in my career.	1.33	3.85

The result of the above t-test for motivation to learn the binary tree and the linked list is summarized in Table XXI. A total number of items which we need to compare using T-test was 17. Table XXI illustrates the mean values of the motivation to learn a binary tree and a linked list for each of the groups (pre-and post-survey). The mean value of motivation to learn in post-survey was 3.69 whereas the mean value of motivation to learn in pre-survey was 2.16.

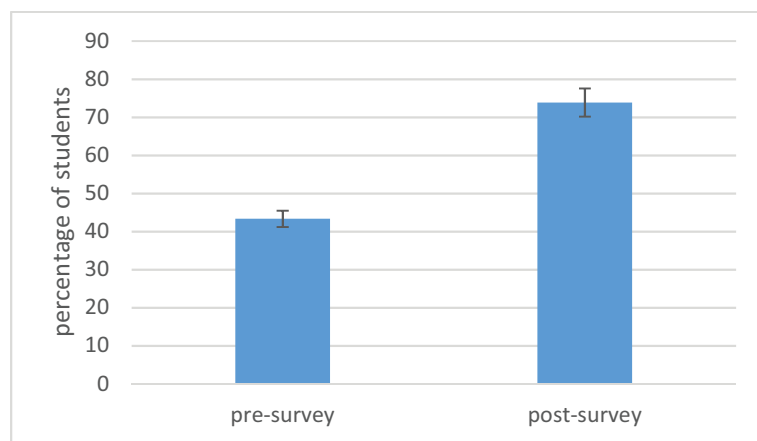


Fig. 52. Mean value of motivation for pre- and post-survey

Additionally, it includes the respective results of the variances of both pre- and post-survey based on motivation to learn linked list and binary tree. The result involves the degree of

freedom, the T values and the critical value of the t-tests. Results show that the degree of freedom (df) for the t-test is 27, t-value (t Stat) is 11.0349, and the critical value (t Critical two-tail) is 2.051831. The results of the t-test for the motivation have shown that t-value (11.0349) is greater than the critical value (2.051831). Additionally, the p-value (1.65E-11) of the t-test is lesser than the hypothesized p-value (0.05). So, we can reject the null hypothesis and; we will accept the alternate hypothesis such that there is a significant difference in motivation to learn when we use GTI module for learning binary trees and linked list.

Table XXI. Results of T-test for motivation to learn

t-Test: Two-Sample Assuming Unequal Variances		
	<i>post-survey</i>	<i>pre-survey</i>
Mean	3.692804	2.165908
Variance	0.094652	0.230832
Observations	17	17
Hypothesized Mean Difference	0	
Df	27	
t Stat	11.03492	
P(T<=t) one-tail	8.24E-12	
t Critical one-tail	1.703288	
P(T<=t) two-tail	1.65E-11	
t Critical two-tail	2.051831	

#### 4.4.6. Evaluation of Likability using Theory Reasoned of Action

For evaluating the likability of the GTI module, we have used "Theory of Reasoned Action (TRA)." TRA is used for determining the relationship between the attitude of the audience (likability) and familiarity with the product or technology. Nguyen and Choudhury [105] used TRA (belief-attitude-intension model) to find the brand likability (refer to chapter 2). 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.

#### **4.4.6.1. Statistical analysis of likability using ANOVA test**

The final study was conducted in the spring semester (N=57) with the graduate and undergraduate students of computer science. All participants were currently enrolled in the introductory programming classes. In the evaluation process, we first gave a demonstration of GTI modules to all participants. The participants (M= 36, F= 21) interacted with the linked list and binary tree instructional modules. Then the students were asked to complete a questionnaire (post-survey) based on TRA (for evaluating likability of GTI modules). The study lasted for approximately 25-30 min. For evaluating the likability of the GTI module, we have used "Theory of Reasoned Action (TRA)." 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 have used ANOVA test for three categories of participants for testing two hypotheses, which includes:

- H8: GTI modules are more likable by the participants having greater familiarity with virtual reality games.
- H9: Students spend more time with the higher level of familiarity with other virtual reality games.

For Hypothesis 8, the results show that the likability of the expert user of virtual reality games is highest among all students. The ANOVA test that we performed shows that the difference was statistically significant ( $p = 6.74E-11 < 0.05$ ). So, the results support our first hypothesis, concluding that greater familiarity results in more likability.

Table XXII. ANOVA analysis of likability of GTI modules

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
novice	16	42.66667	2.666667	0.355556
intermediate	16	49.66667	3.104167	0.425463
expert	16	71.33333	4.458333	0.235185

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	27.9213	2	13.96065	41.21412	6.74E-11	3.204317
Within Groups	15.24306	45	0.338735			
Total	43.16435	47				

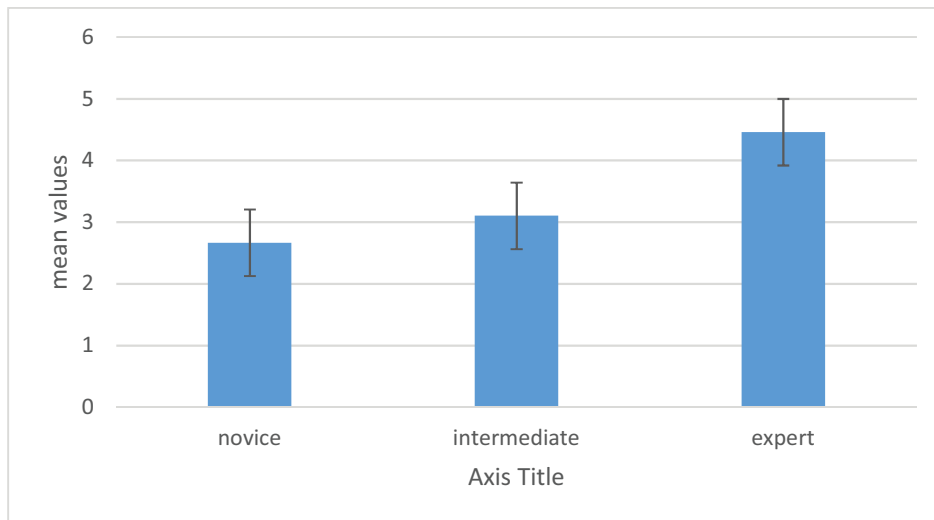


Fig. 53. Mean of the likability with all three categories.



The mean of the likability with all three categories is shown in Fig. 53. From the fig. 53, we can infer that the students having greater familiarity have more likability towards GTI modules. The error bar on bar graphs shows the likability of GTI modules with a 95% confidence level.

Regarding hypothesis 9, the result shows that the participants who are more familiar with virtual reality game spend more time with GTI modules. The result of ANOVA analysis indicates that the difference was not statistically significant ( $p = 0.186 < 0.05$ ). Although the expert player 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 mythology of learning.

Table XXIII. ANOVA analysis of hypothesis (H9)

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
novice	16	47	2.9375	2.729167
Intermedia	16	47	2.9375	2.0625
expert	16	60	3.75	1.266667

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.041667	2	3.520833	1.743466	0.18652	3.204317
Within Groups	90.875	45	2.019444			
Total	97.91667	47				

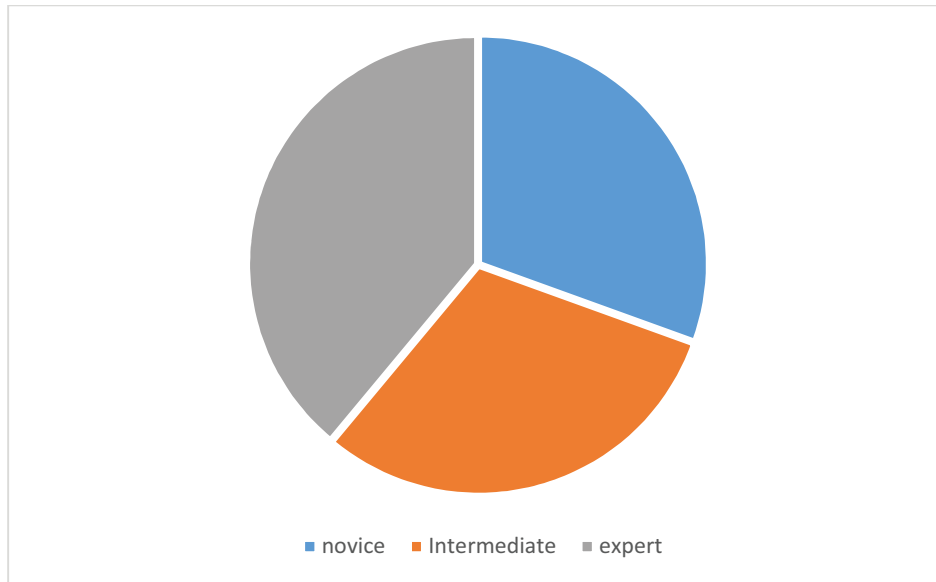


Fig. 54. Time spent with GTI modules for all three categories of students.

The mean of the time spend with GTI modules for all three categories is shown in Fig. 54. As shown in the figure.54, the novice and intermediate player spends almost same time with the GTI modules whereas expert player spends more time with the GTI module. From the result of ANOVA analysis, we can infer that the difference in time spends with GTI modules was not significant for expert, intermediate or novice users.

#### 4.4.7. Evaluation of usability using User Engagement Scale (UES)

Usability of 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. We have evaluated the usability of GTI modules by using a mixed approach which includes: (1) quantitative and, (2) qualitative methods. The quantitative analysis of the usability of GTI modules is based on "User

Engagement Scale (UES)." Several researchers have developed questionnaires for the evaluation of user engagement. UES was built using an iterative method of evaluation and scale development which involved: (1) collection of data, (2) assessing the validity of data, (3) 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 the system having 31-items that comprise six dimensions. There are already many researches have been examined the usability of UES for measuring user engagement.

The user engagement scale has six dimension which includes:

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

#### **4.4.7.1. Qualitative analysis of usability using grounded theory**

The qualitative analysis of Usability was done using the "Grounded theory." According to Glaser and Straus, the grounded theory is an approach that relates to "the discoveries of theories" from the collected data, and it is not based on any pre-determined theoretical framework. The grounded theory is also known as "emergence theory," as the speculations (theories) emerges from the observed data instead of a pre-defined hypothesis. The qualitative analysis of the usability was accomplished from the observed data. We have collected data during the evaluation

process of GTI modules, then we empirically tested the data and generated the conclusion about the usability of GTI modules.

We have evaluated the GTI modules in the spring semester with 61 students (36 males, 21 females, 4 skipped the evaluation). We have collected the data for qualitative analysis while the students were using the GTI modules in the classroom. The analysis was based on three sources of insight, which includes:

1. The number of students asked for technical help.
2. Students stopped using the GTI modules and started working some other task.
3. The number of students got annoyed/frustrated (eye tracking) due to navigational (how to proceed) problem and asked for help.

Table XXIV. Qualitative analysis of Usability

Observation no.	Sources of insight	Number of students	Percentage of students	No. of students did not ask for help, didn't lose interest, or didn't get frustrated	Percentage of students did not ask for help, didn't lose interest, or didn't get frustrated
1.	The number of students asked for technical help.	5	8.77%	52	91.12%
2.	Students stopped using the GTI modules and started working some other task.	4	6.56%	57	93.44%
3.	The number of students got annoyed/frustrated (eye tracking) due to navigational (how to proceed) problem and asked for help.	3	5.26%	54	94.74%

From the Fig. 55, we can observe that 8.77% of students asked for help whereas 91.23% students did not ask for any technical help. We can also see that only 6.56% of students did not show interest in GTI modules all other students were involved in the evaluation process of GTI modules. Additionally, only 5.26% students get annoyed/frustrated due to navigational (how to proceed) problem and asked for help whereas 94.74% students did not have a navigational problem with GTI modules. So, we can conclude qualitatively that GTI modules are usable.

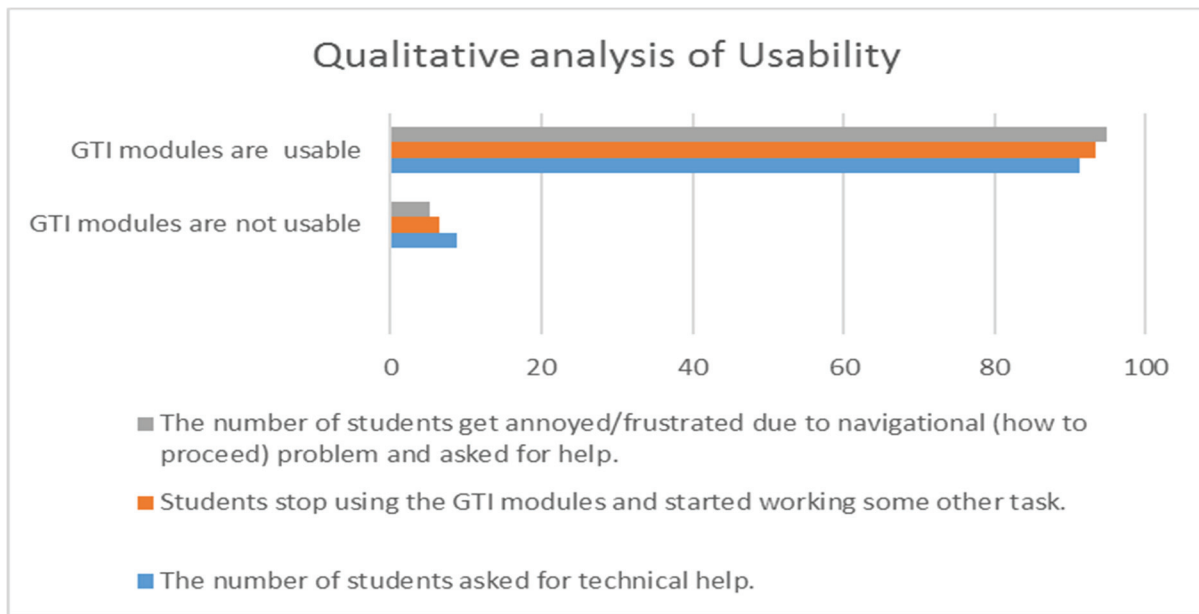


Fig. 55. Qualitative Analysis of Usability

#### 4.4.7.2. Quantitative analysis of usability

We have used the User Engagement Scale (UES) for the quantitative analysis of GTI modules to teach linked list and binary trees. UES is a self-reporting questionnaire to evaluate the usability of a software tool. We have modified the wording of the UES items to fit in the game theme based learning context. Original UES has 31 items, and it is divided into six sub-categories such as FA, FI, NO, EN, AE, and Pus. We have also excluded a few questions which are not applicable to our research. We created total 28 questions for the evaluation of GTI

modules based on UES. We have used a five-point Likert scale ranging from "Always" to "Never."

After collecting the data from the introductory programming classes, we have used the following procedures and tests to examine the data (table XXV).

- We have done the missing value analysis on each item and ignore the incomplete data for further analysis.
- We have calculated the Cronbach alpha to examine the reliability of all the six subscales of the UES.
- We have calculated the average (mean) value and standard deviation of data.

Table XXV. Quantitative analysis of usability

Subscale	Mean (M)	standard-dev (SD)	Cronbach alpha
EN	3.51634	1.36	0.970013
FI	3.446078	1.36	0.973277
FA	3.294118	1.30	0.990635
NO	3.431373	1.27	0.968189
AE	3.47451	1.34	0.983102
Pus	3.27451	1.20	0.965901

We have used Cronbach alpha to examine the reliability of the subscales of the UES. If the values Cronbach alpha lies between 0.7 and 0.9 then the scale is considered as optimal. From the table XXV, we can see that the Cronbach alpha for the subscale lies between 0.96 to 0.99. So, we can conclude that the scale UES is highly reliable. UES item (subscale) means ranged from 3.27 to 3.52 (on a five-point Likert scale) and the standard deviation ranges from 1.2 to 1.36. The outcomes from survey data showed that the mean value for all the six categories of UES ranged

from 65.4% to 69.9% . So, most of the students thought that GTI modules were usable quantitatively.

#### **4.4.7.3. Corroboration of Quantitative Results of learning gain in Qualitative**

##### **Responses of users**

Usability of GTI module is one of the vital aspects of evaluation. We have analyzed the usability of GTI module by corroborating the quantitative results with the qualitative outcomes. We have analyzed the usability of the GTI module for the hypothesis (H10).

- H10: GTI module is usable.

For usability, the qualitative analysis is more critical than quantitative analysis. We have done qualitative analysis based on the three physiological measures which includes: (1) asking help for technical problem with GTI modules, (2) navigational effort while using GTI module (keyboard and mouse tracking), and (3) students lost interest in GTI module (eye tracking) in the evaluation process. After acquiring the data based on physiological measures, we have applied grounded theory to generate the conclusion. The empirical results of the qualitative analysis show that there are minimal technical difficulties or navigational problem with the GTI modules. We have used a proven questionnaire "UES" for quantitative analysis of the usability of GTI modules. The empirical analysis of post-survey shows that the GTI modules are usable (section 4.4.4.2). After involving every aspect of the qualitative and quantitative analysis of GTI modules, we have corroborated the quantitative results of usability in the qualitative responses of users (table XXVI). After corroborating the qualitative empirical results with the quantitative outcomes from post-survey, we found the average score of usability of GTI modules is 86.88%.

So, we conclude that our hypothesis (H10) is correct and the GTI modules (linked list and binary trees) are significantly usable.

Table XXVI. Corroboration of qualitative and quantitative analysis of usability

Usability measures	Outcomes in percentage
No. of students did not ask for technical help (observational)	91.23%
No. of students did not lose interest (didn't stop using GTI modules).	93.44%
No. of students successfully navigates through the GTI modules (no aimless movement or disability to move).	94.74%
Post-survey outcomes based on UES	68.12%
<b>Average =</b>	<b>86.88%</b>



## CHAPTER 5

### SUMMARY AND CONCLUSIONS

#### 5.1. Conclusions

The GTI (Game Theme based Instructional) modules were based on gaming metaphor to teach the concepts of introductory programming. We have designed and developed two GTI modules which are used: (1) to teach binary trees, and (2) to teach the linked list. We have incorporated the four-dimensional framework (FDF) with a minor extension for design and development of GTI modules (refer to Chapter 3). The GTI modules can act as a supplement to the existing class to teach the concepts of the linked list and binary trees. Students (N=14 for summer 2017 and N=57 for spring 2018) chosen for the research study were based on (1) they are enrolled in introductory programming courses (2) age between 18-25years old (3) exposure to software games. All qualified candidates completed an analytical survey after working on the GTI modules to learn binary tree and linked list concept. The data were analyzed using statistical analysis methods. We have evaluated GTI modules with 57 students (42 undergraduate students and 15 graduate students) during the spring semester and 14 students (8 undergraduate students and 6 graduate students) in the summer semester (phase I).

We have applied proven evaluation scale/methodology for the evaluation of the effectiveness of GTI modules, which includes:

- 1) Student Assessment of Learning Gains (SALG) survey to evaluate the learning gain from GTI modules.
- 2) Science Motivation Questionnaire II (SMQII) for evaluating the motivation of students to learn binary tree and linked list, from the usage of GTI modules.

- 3) User Engagement Scale (UES) for evaluating the usability of GTI modules.
- 4) Theory of Reasoned Action (TRA) for evaluating the likability of GTI modules.

The outcomes shown in chapter 4 are consistent per our hypothesis that there is a significant difference between the learning gain of students when they use GTI module to learn binary tree and a linked list. We have done the t-test for learning gain using the mean values of samples from pre-and post-survey. The result of the user study (t-test for learning gain) demonstrates that t-value (10.03258) is greater than the critical value (2.012896). Additionally, the p-value (3.67E-13) of the t-test is lesser than the hypothesized p-value (0.05) (refer to chapter 4). So, we can conclude that the GTI modules have enhanced the student understanding of the linked list and binary trees concepts. We have also done the qualitative analysis for learning gain based on grounded theory. Based on the students' feedback (80.89% comments were positive towards GTI modules), we can conclude that there is considerable learning gain when the students use GTI modules to learn the concepts of the linked list and binary tree.

In this research, we have evaluated that the GTI modules motivate the students toward learning. We have used SMQII questionnaire to evaluate the motivation of students towards learning (concepts of the linked list and binary tree) when they use GTI modules. For statistical analysis of motivation towards learning, we have incorporated a t-test using the sample mean of pre-and post-survey. The outcomes of the statistical analysis (t-test) for the motivation have shown that t-value (11.0349) is higher than the critical value (2.051831). Besides, the p-value (1.65E-11) of the t-test is lesser than the hypothesized p-value (0.05). So, we can conclude that students felt motivated and engaged in learning. The result of the empirical evaluation (mean value) shows that 74% of students got motivated when they used GTI modules for learning.

Likability is one of the essential aspects of the software tool (GTI modules). For evaluating

the likability of GTI modules, we have created the questionnaire in post-survey based on TRA using belief-attitude-intension model. In chapter 4, we have done the evaluation of likability of GTI modules is based on two hypotheses which include: (H4) GTI modules are more likable by the participants having greater familiarity with virtual reality games; and (H5) Students spend more time with the higher level of familiarity with other virtual reality games. 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 players such as (1) novice, (2) intermediate and, (3) experienced. Then we used the ANOVA test for the hypothesis H8 and H9. For Hypothesis H8, the results showed that the likability of the expert user of virtual reality games was highest among all students. The ANOVA test ( $p = 6.74E-11 < 0.05$ ) showed that the difference between the three groups was statistically significant. So, the results supported our hypothesis, concluding that greater familiarity results in more likability.

Regarding hypothesis H9, 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 ( $p = 0.186 < 0.05$ ) indicated that the difference was not statistically significant. 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. Based on the students' feedback, we can conclude the GTI modules are exciting or likable.

Usability of the GTI modules is one of the most vital aspects for finding the effectiveness of the GTI modules. We have done both qualitative and quantitative analysis for the evaluation of

Usability. For usability, the qualitative analysis is more critical than quantitative analysis. The qualitative analysis based on the physiological measures (asking for help, eye tracking, lost interest) was done while the students were using GTI modules in the evaluation process. We have collected the data during the evaluation and; then applied grounded theory to generate the conclusion. The outcomes of the qualitative analysis indicate that there are no technical difficulties during the navigation through the GTI modules (refer to chapter 4). For the quantitative analysis of the usability of GTI modules, we have used a proven questionnaire "UES." After thoroughly going through the qualitative and quantitative analysis we have corroborated the quantitative results of usability in the qualitative responses of users. The outcomes of corroboration of the qualitative empirical results with the quantitative outcomes from post-survey shows that average score of usability of GTI modules is 86.88%. Thus, we have concluded that the GTI modules (linked list and binary trees) are usable.

In conclusion, we believe that the GTI modules have attained the positive outcomes in all four aspects which includes: (1) learning gain, (2) motivation of students towards learning, (3) likability and, (4) usability. So, the GTI modules can be included as a supplement in the regular class curricula to teach linked list and binary trees.

## **5.2. Future work**

The objective of virtual reality-based games is to provide the users with 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 a head mounting display, data gloves, and oculus rift. The virtual reality hardware provides the users a full virtual immersion as well as six degrees of freedom. Our proposed GTI modules incorporate non-immersive virtual reality. The students can interact

with the game using desktop monitor, keyboard and mouse. The GTI modules can be converted into an immersive virtual environment using hardware like oculus rift. Virtual reality hardware is expensive and currently, we do not have enough virtual reality hardware; so, we cannot provide these hardwires to all students in the classroom. For the foreseeable future as technology advances, we are expecting the virtual reality hardware will become affordable. Therefore, one of the future work regarding GTI modules is to make these modules immersive. Additionally, we can also incorporate augmented reality inside the GTI modules.

Future work will also include evaluation of (GTI module to teach binary trees and linked list) with more students. 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. Forthcoming work will be dedicated to the design and development of GTI modules on other concepts such as multidimensional arrays, stack, queues or any other programming concepts that the learners struggle to understand.

## APPENDICES

### Appendix A - Definition of Terms

1. **GTI modules:** is a game theme based instructional modules to teach introductory programming concepts.
2. **Virtual reality (VR):** is a computer-generated environment that helps the user to immerse in the virtual world.
3. **Augmented reality (AR):** is defined as a system which permit the existence of virtual object in real space and both the real object and virtual object interact in real time.
4. **Vizard:** is a virtual reality software tool kit, which is used for creating, rendering and, deploying 3-D visualization and simulation application. Vizard support various hardware devices including head mounted display, data gloves, cave oculus rift and, gamepad.
5. **Python:** Python is used in Vizard as programming language; python is the world's most approachable scripting language. It has very concise statement and syntax. It has robust open source libraries and toolkits.
6. **oculus rift:** is a virtual reality hardware tool, which allow immersing in virtual world, just by wearing the head set. The oculus rift has six degrees of freedom including three transitional and three rotational movement tracking.
7. **3D-max:** is a 3D modeling, rendering and animation software application which helps in creating virtual environment.
8. **Sketch-up:** is a software which helps in 3D-modeling.
9. **Virtual Instructor:** is a 3D-modal (avatar) who helps the end-users/ students during gameplay.
10. **Simulation:** replication or recreation model

11. **FDF:** is a four-dimensional framework used to evaluate the effectiveness of game or simulation based learning.
12. **SALG:** Student Assessment of Learning Gains focuses exclusively on the degree to which a tool has enabled student learning.
13. **SMQII:** Science Motivation Questionnaire II (SMQII) is used for evaluating the motivation of the students to learn. SMQII assessed five motivation components: Intrinsic motivation, Self-determination, Self-efficacy, Career motivation and, Grade motivation.
14. **TRA:** Theory of Reasoned Action is used for determining the relationship between the attitude of audience (likability) and familiarity with the product or technology.
15. **UES:** User Engagement Scale is a self-report measuring technique which consists of 31 items and implied to measure the usability of the software.

## Appendix B: IRB



**Graduate School Office  
Center for Business and Graduate Studies**

### MEMORANDUM

Application Approval Notification

**TO:** Dr. Sharad Sharma

**FROM:** Cosmas U. Nwokeafor, Ph.D.  
Chair, IRB  
Bowie State University  
Bowie, MD 20715

**RE:** **IRB Number 018-001**  
**Project Title: “Game theme based instructional  
modules based on usability”**

**Approval Date:** February 1, 2018

**Expiration Date:** February 1, 2019

**Type of Application** New Project

**Type of Research:** Nonexempt

**Type of Review  
For Application** Expedited

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The Bowie State University Institutional Review Board (IRB) has extended your approved IRB Proposal application in accordance with 45 CFR 46, the Federal Policy for the Protection of Human Subjects and the Bowie State University's IRB guidelines and procedures. Please reference the above-cited IRB application number in any future communications with the Board regarding your research.

**Recruitment/Consent:** For research, requiring written informed consent, the IRB-approved and stamped informed consent document will be enclosed. The IRB approval expiration date has been reserved. Please keep copies of the consent forms used for this research and this memorandum for three years after the completion of the research.

**Continuing Review:** If you intend to continue to collect data from human subjects or to analyze private, identifiable data collected from human subjects, after the expiration date for this approval (indicated above), you must submit a renewal application to the Chair of BSU IRB at least 30 days before the approval expiration date.

**Modifications:** Any changes to the approved protocol must be approved by the IRB before the change is implemented, except when a change is necessary to eliminate apparent immediate hazards to the subjects. If you would like to modify the approved protocol, please submit an addendum request to the IRB Chair. The instructions for submitting a request could be obtained from IRB Chair.

**Unanticipated Problems Involving Risks:** You must promptly report any unanticipated problems involving risks to subjects or others with your application.

**Student Researchers:** Unless otherwise requested, this IRB approval was sent to the Principal Investigator (PI). The PI should pass on the approval document or a copy to the student researchers. This IRB approval document may be a requirement for student researchers applying for graduation. The IRB Chair may not be able to provide copies of the approval documents if several years have passed since the date of the original approval.

Congratulations and best wishes on the completion of your study.

**Additional Information:** If you have any IRB related questions or concern, please contact:

**Dr. Cosmas U. Nwokefor, Chair IRB**  
Center for Business and Graduate Studies  
Suite 1312  
Bowie State University  
Bowie MD 20715  
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