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Investigating the Effectiveness of Learning Data Structure and Algorithm (DSA) Programming using Augmented Reality

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ABSTRACT

The COVID-19 pandemic has paved the way for rapid technological advancements, bringing about significant changes in teaching and learning methods. Augmented Reality (AR), an emerging technology, has emerged as an effective approach to improve the user experience and comprehension by providing a realistic view of concepts data structure objects. Educators have been actively working to transition from traditional or conventional learning styles to the process of learning using augmented reality application in order to improve the effectiveness of the level education system. This transition aims to improve individual students' learning, motivation, and facilitate more effective teamwork and group cooperation. One crucial course for computer science students is Data Structure and Algorithm (DSA), which serves as a prerequisite for several other courses. DSA poses challenges as it provides crucial concepts for programmers in efficiently handling data. A solid foundation in data structure and algorithm influences programmers able to efficiently write and develop cost for the effective solutions. However, many computer science students, especially those lacking a strong programming background, struggle to grasp the concepts of algorithm in DSA. This difficulty in understanding DSA concepts often leads to apprehension among students, making them hesitant to pursue a career as programmers after graduation. This research aims to address these challenges and has identified several objectives to achieve its goal. The objectives include analyzing and designing application features that attract students to learn DSA in an interactive manner, developing an AR application that facilitates user-application interaction, and investigating the effectiveness of the AR application in terms of usability, acceptability during the DSA learning process.

1. Introduction

Augmented Reality (AR) is widely recognized as an interactive experience that overlays virtual elements onto the real world. Educators worldwide have been exploring the integration of augmented reality into the education system to enhance its effectiveness. By utilizing AR technology, individual students' learning experiences can be improved, their motivation can be boosted, and they

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can develop better teamwork and group cooperation skills. Research has demonstrated that augmented reality applications offer cognitive and experiential enhancements, which contribute to a more realistic and engaging learning environment. These advancements not only facilitate systematic learning but also provide opportunities for collaborative learning and the development of innovative representations of real-world objects. As a result, various AR apps have already been implemented across different courses to connect students with new knowledge and increase classroom engagement [1].

Despite the extensiveness use of AR technology in ICT area and also STEM education, its application in programming education is still relatively new. However, integrating AR technology into programming education holds immense potential. It expands the range of teaching strategies, work formats, and learning processes available in the programming field, leading to the modernization of education and the improvement of educational processes. Previous studies have shown that augmented reality can effectively engage students in systematic learning for the development of new representations of real objects and also collaborate learning process [2]. By incorporating various AR applications, the potential of AR technology to connect students with programming languages can attract their interest and enhance their understanding of this field.

The structure of this paper is as follows: Section 2 will provide a review of previous research in this area; While Section 3 described the methodology that has been adopted for this project; Then, Section 4 presented the implementation of the project, starting from phase 1; In Section 5 outlines how the evaluation process of pre-questionnaire has been conducted; and finally, the paper concludes the contribution of the paper in the domain with the summary of the project.

2. Review of Related Works

2.1 Augmented Reality Technology

The augmented reality is one of technology that uses the existing object in real world environment, and it will be designed to enhance the experience by putting virtual information. With this technology we can visualize the object especially for programming. The AR has been divided into two components, whereby the first is known as marker-less AR and second component is known as a marker-based AR. Each of the components have their own objectives to achieve the goal enhance the experience. The process of detection a camera in order to detect the existence of the selected marker, the marker-based AR will apply a camera. The process of detection the visual markers or objects will only shows an overlay when the device detects the marker. Furthermore, the marker-less AR uses a digital or GPS compass to give position data and the AR visualizations that will be triggered depending on these inputs [3].

2.2 Implementation of Augmented Reality Application in Education

In the present day, it has been demonstrated that the modernization of the education system and the introduction of innovative learning technologies can greatly enhance the educational process. Researchers have highlighted the positive impact of utilizing augmented reality (AR) applications, designing concepts, and providing a suitable hardware environment on learning environment and learners' cognitive load [4]. Augmented reality often stimulates students' engagement in learning activities and fosters the development of advanced skills. It also facilitates collaborative project work, as students frequently collaborate in groups. While augmented reality is commonly associated with gamification, it is actually an information communication technology that can create interactive learning environments for students. The most significant outcome is the long-

term experience that can inspire students to continue their studies and actively involved in any activities in school either academic or non-academic [2,5].

Extensive existing research has been conducted to investigate the used of application augmented reality in education, demonstrating numerous advantages of employing AR that lead to improved student outcomes. For instance, AR technologies have allowed students to visualize algebraic surfaces to different extents in the field of mathematics, aiding their understanding of mathematical concepts [6]. In the domain of chemistry, AR technologies enable students to comprehend the structure of atoms and molecules, conduct experiments that are costly or hazardous in the real world, and observe chemical reactions [7]. Similarly, in biology, AR technologies facilitate the scaling of organs, cells, and DNA molecules, providing interactive visualization tools for static and dynamic charts, such as those illustrating the process of DNA replication (Laine & Suk, 2016). These examples demonstrate how the integration of AR in education motivates students to learn and enhances their mastery of programming concepts [8].

AR technology functions by utilizing the sensors of devices to perceive the real world and augmenting it interactive content in digital ways. The ability to process the visualization in the learning environment and also enhance object through interactive digital information has sparked interest in utilizing AR technologies for improvement the experiences especially in in the educational purposes [2]. Various content visualization technologies, including diverse and interactive visual presentations of instructional materials, as well as the migration of certain research work into the virtual realm, have shown the effectiveness of AR technologies in education. However, the availability of numerous learning subjects that can be enhanced with AR technologies was comes with a multitude of platforms and technologies that can be employed to create experiences using augmented reality [5]. It is important to note that effectively utilizing AR technologies requires a fundamental learning process to familiarize oneself with specialized software or platforms used for creating customized mobile applications [9].

2.3 Implementation of Augmented Reality in Teaching Programming Courses

Learning programming languages can be challenging, especially for non-science students, as it requires an understanding of programming logic [3]. Additionally, teaching programming poses difficulties for educators as selecting appropriate tools for instruction is crucial and influenced by various criteria such as age appropriateness and motivating characteristics [8,10]. In recent years, limited research has been conducted on utilizing AR technologies to enhance programming learning, focusing on teaching basic programming concepts through engaging games and removing the need to worry about syntax or program flowcharts [2,8]. One challenge in using program flowcharts is that students must comprehend how each command functions and predict the outcome when executing commands in the flowchart. AR tools provide a solution to this issue by allowing students to visualize the result of each command, leading to a better understanding of the logic behind programming [3]. By using AR markers, students can construct program flowcharts by sequencing commands, and the execution results of these commands can be displayed, enabling students to assess the correctness of the program's logic. The use of AR tools has been proven to enhance student engagement and understanding of program logic [3].

One more example that can relate to the process of integrating AR technology in programming learning include using head-mounted AR devices like mobile AR with ARKit on device such as an iPhone, Microsoft HoloLens, and also might be a traditional 2D touch interface with Swift Playground on device such as an iPad as a baseline [11]. Experiments using these technologies have yielded positive feedback, as the real-time visual feedback provided by the augmented reality environment

improves coding and planning skills when completing programming tasks. This demonstrates the potential of AR in enhancing beginners' learning experiences in programming [12].

Mobile application development, specifically using MIT App Inventor 2, has gained popularity in teaching students how to create mobile applications by integrating AR technology [13]. This platform enables users to build mobile applications without programming skills by implementing a visualization of how the programming approach working, where different components are selected and will be integrated in order to create a program. AR capabilities, when incorporated into this context, dynamically the real-world learning environment has been overlay digital content, by providing students with a context-aware learning environment for writing and compiling programming codes in a problem-solving manner [7]. Furthermore, deep learning approaches combined with AR have shown effectiveness in teaching programming languages, as they address misconceptions and promote active comprehension, problem-solving skills among students, and critical thinking [7].

3. Methodology

There are many ways and examples regarding developing a good AR technology in programming. However before introducing AR-based learning tools especially that need considerable user participation, usability difficulties must be addressed carefully since it has been reported that difficulties of using AR learning tools in a school setting amongst students upon deployment [3]. It has been suggested that the learning experience should be in developing AR technology in education and the components examples that need to take into account are concept, content, software and hardware where all these elements play a huge influence on the learning process. Table 1 shows further descriptions regarding the components. This project adopted Waterfall Life Cycle methodology to develop the AR application.

Table 1
Component of AR learning tool development

Components	Description
Concept	The notion of utilizing interactive AR to teach fundamental programming where students can view the outcome from a flowchart diagram. Each flowchart notation may be substituted by an AR marker, and the process flow can be depicted utilizing marker-marker interaction using this notion.
Contents	Students must practice solving numerous issues in order to develop programming skills; hence a variety of tasks should be possible to set while utilizing this tool. As a result, students will be able to create a flowchart to address the problem, similar to how they would arrange the flow of commands, and they will be able to demonstrate that they understand the sorts of commands as well as the sequence of commands in the flowchart.
Software	The software application should be designed to take an image of the flowchart that has been created, process the program, and display the command execution results. It should be able to recognize the command, the value of the variable, and the Boolean operator from the captured image
Hardware	The equipment used should be able to follow commands in a flowchart and able to be used as an input device while running the programmes. It may also be used as an output device to project a digital image onto a physical object and shown in real time as it may display smoothly.

After all the research and findings regarding teaching and learning using AR in programming, it can be concluded that the effectiveness of teaching programming using the support of AR technology is able to have a positive outcome towards students. For this project, the proposed methodology as depicted in Figure 1. There are four phases that has been proposed to achieve the three objectives.

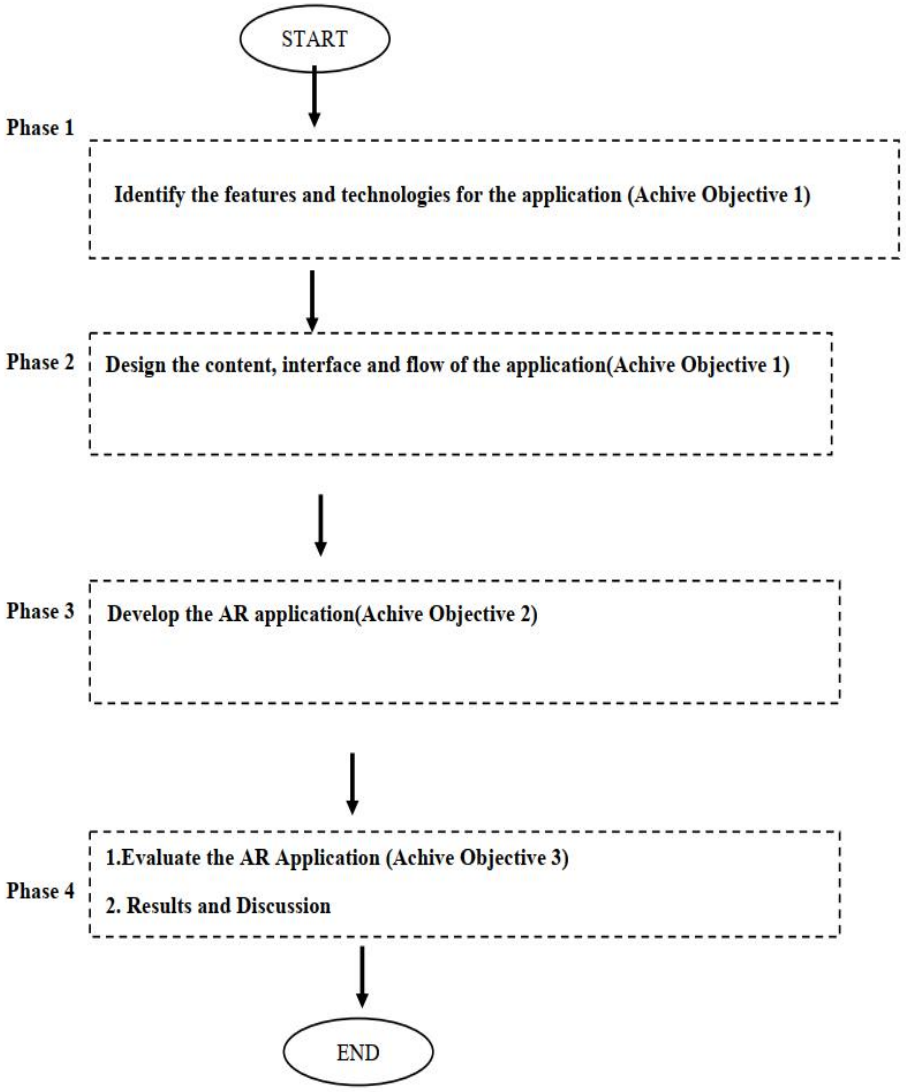

Fig. 1. Proposed methodology for the project

The methodology is important to make sure that the project reach the aims that has been defined earlier. Phase 1, process of identify features and technology for the application. In this phase, the process of identifying the features of the application will reflect the chosen technology that will be used in development phase. The operating system being utilized is employed to operate the Unity Version 2019.4.23f1, alongside Vuforia 8.1.12. Unity, an application software developed by Unity Technologies, serves as a game engine that allows users to design and create two-dimensional (2D) or three-dimensional (3D) applications. Additionally, Unity offers various toolkits, such as Vuforia, which facilitate the development of virtual reality (VR) or augmented reality (AR) applications, simplifying the process for users. Consequently, the Vuforia SDK is employed to create marker-based AR applications. Furthermore, the minimum of specification of device for Android OS requirement for this project is Android 4.4 KitKat version, while the implementation of coding has been used a Asus Notebook is utilized for the system development aspect of this project [14].

Phase two involves designing the content, interface, and finalizing the flow of the augmented reality (AR) application. This stage requires reviewing and identifying the DSA concepts that would benefit from AR to enhance student understanding [15]. Additionally, the comments entered by students in the exit survey are considered as input for this phase. Based on the selected DSA

concepts, the workflow of step by step for each concept is designed, starting from the concept's background and extending to the interface design. Two workshops involving DSA experts from the faculty are conducted to design the markers, quiz questions, and select appropriate code for implementing the AR. Completing phases one and two will allow the achievement of Objective 1, which involves analysing and designing features suitable for specific DSA concepts.

Phase three focuses on developing the AR application based on the requirements gathered in phases one and two. The completion of this stage will enable the achievement of Objective 2, which is to develop an AR application that facilitates interaction between users and the application during the process of learning DSA programming [15]. The proposed application consists of two modes: the first mode includes AR tracking and virtual 3D content, while the second mode is designed to evaluate students' understanding of selected topics through quizzes.

Phase four involves the process evaluation of the AR application. This phase aims to assess the functionality, usability, and acceptability of the AR application during the learning process of the DSA course. The evaluation will be conducted with 100 second-year Software Engineering students who have varying programming abilities and augmented reality experience [2]. The evaluation results will be obtained through questionnaires distributed to the 100 students and 10 DSA lecturers. To comply with the Objective 3 of this project, the AR application will be evaluating to measure the degree of acceptance in terms of the functionality of the application, usability, and acceptability during the learning process of the DSA course.

4. Implementation for Development Phase 1 and Phase 2

As mentioned in the methodology, the first phase is process of identify the selected DSA concepts based on the lecturers DSA feedback and also from the exit survey that answered by students before end of semester [10]. The output of the first workshop is, selected two topics, which is Singly Linked List, Merge Sort, and Advance Sort. Based on the discussion during the first workshop, few design has been finalize before start with the development phase. Figure 2 shows the main page of the AR application.

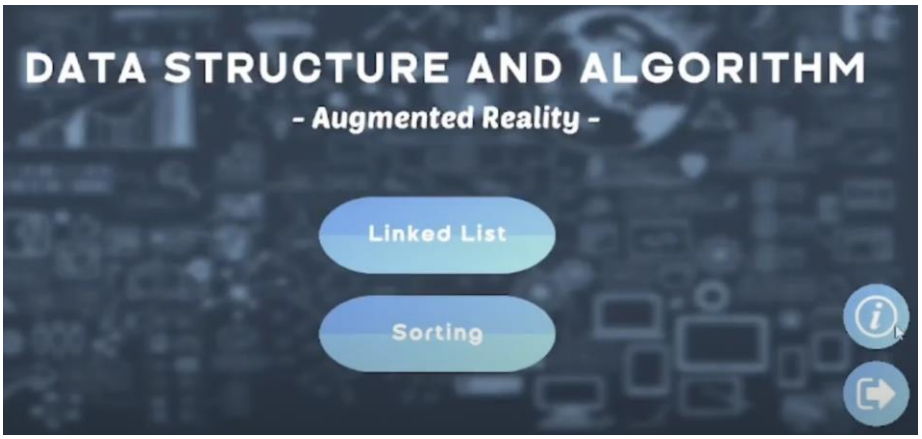

Fig. 2. Main page of AR application

While Figure 3 shows the flow of the main topic screen to the next screen. Example in Figure 3, it shows that for topic Linked List, there are potential screens to cover for the Linked List topic. There are various types of Linked List but for this project, only Singly Linked List will be implemented. The Circular Linked List and Doubly Linked List will be implemented in next phase project.

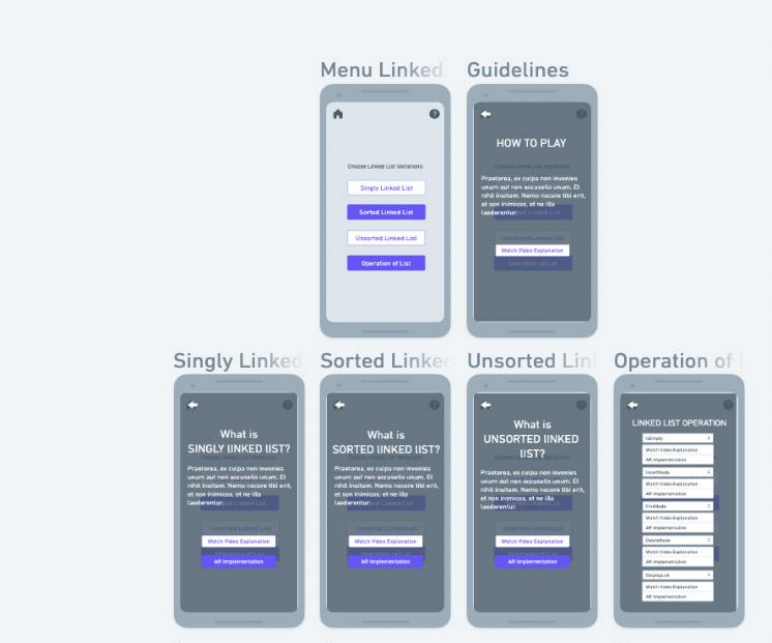

Fig. 3. Screen design for the topic Singly Linked List

Before the phase development get started, the flow of how the animation in AR will be implemented as presented in Figure 4. The Figure 4 shows that the code in C++ will be based to design the animation for the AR. Based on the output for the first phase of the development, few things need to redesign so that the AR application will become clearer and meet the learning outcome. As mentioned earlier, the first mode development is implementation of virtual 3D content whereby for this project is the process of creating a list of markers based on selecting C++ codes [2]. This process including the information of how the movement of object in the application based on line of codes presented in the marker as shown in Figure 4. At the first stage, the 3D C++ codes will be displayed based on the marker that has been set in the Vuforia. Next step will be the animation that showing movement of an object, for example in Figure 4 shows that the head node is moving to second node which a value of 5. This animation reflects the line of code 11. The animation movement of the node object is crucial as it must same as the algorithm concept [16].

Inserting a new node (will create a sorted list)

```
Node* List::InsertNode(double x) {

        int currIndex = 0;
        Node* currNode = head;
        Node* prevNode = NULL;
        while (currNode && x > currNode->data)
                prevNode = currNode;
                currNode = currNode->next;
                currIndex++;
        }

        Node* newNode  =       new     Node;
        newNode->data  =       x;
        if (currIndex == 0) {
                newNode->next  =       head;
                head           =       newNode;
        }
        else {
                newNode->next  =       prevNode->next;
                prevNode->next =       newNode;
        }
        return newNode;
```

ANIMATION

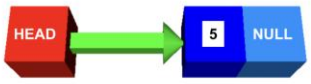

Fig. 4. Snippet code for the add new node Singly Linked List

The second mode is quizzing whereby the implementation of lean touch library that has been applied to each game object to enhance the interaction between user and game. With this feature, user is flexible to resize, rotate, and move position of the game object on the screen device. LeanPinchScale has been used to get the desired game object. While in order to allow the user to choose position when a finger touch the device scree, LeanDragTranslate is used. Finally, LeanTwistRotateAxis is added to allow user do rotation game object. Single image target is used in this application to make the chosen marker more interactive.

The main objective of this application is to increase the student understanding in codes. The animation of the concept student can get freely at any public social media or websites. In this project, from the C++ codes itself students are able to understanding step by step of the codes. Before the implementation of insert and delete operation, the explanation about how the concept of Linked List also been provided using graphical representation as shown in Figure 5. From the representation, students able to know the important component in Linked List before implement it in codes. The output of the implementation of design in Figure 4 as depicted in Figure 6 below.

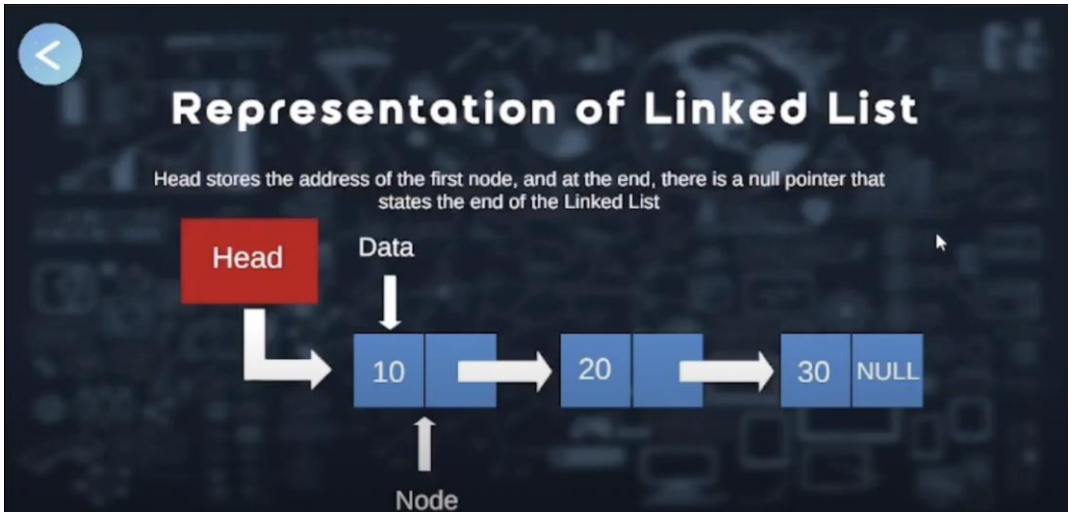

Fig. 5. Representation of the Linked List

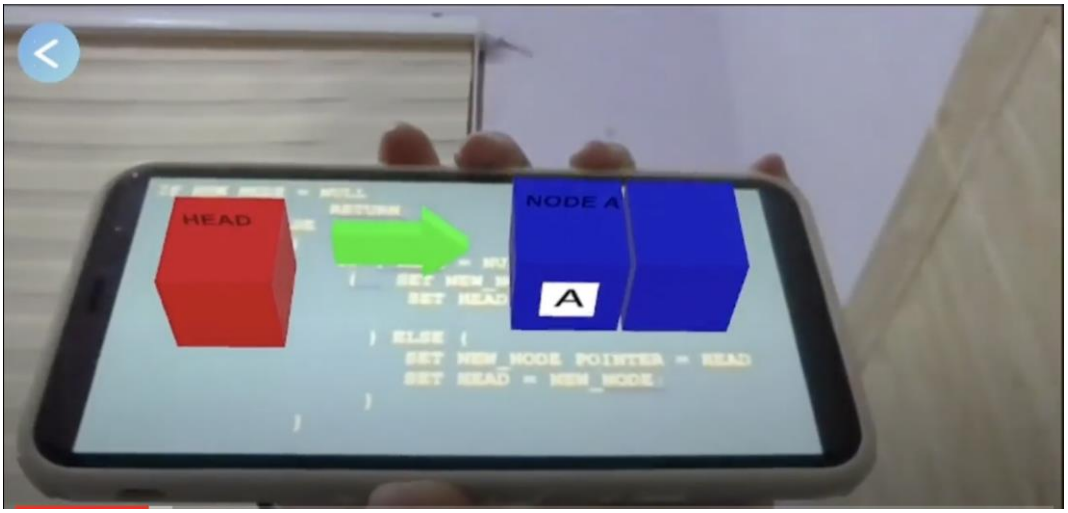

Fig. 6. Output of the design for the add new node in Singly Linked List

During the second workshop, the team of the project has been discussed few enhancements of the output of phase one development. The enhancement including how step by step the AR animation could help the students to increase their understanding codes more clear. Instead of Singly Linked List, Advance Sorting topic is included in this project. There are few sorting techniques in DSA but the selected techniques was the most difficult concept to understand which is Merge Sort and Quick Sort. The enhancement also included simple quiz to evaluate the students understanding in terms of the coding. The quiz question will be totally based on the C++ codes and it covers topic Singly Linked List, Merge Sort, and Quick Sort.

5. Evaluations

The evaluation of the effectiveness of the AR project will be evaluated by students that take DSA in Sem 1 2022/2023. The students will go through the traditional learning process for topic Singly Linked List using notes. Then the student will used the AR application. To evaluate the objective of this application, student will be given a survey that ask their opinion about the AR application. The result of the student attempt the quiz also will be recorded for the evaluation purpose. The quiz will be develop using the AR approach so that student able to sync it with the learning objective to learn DSA using an AR application. For initial study, the application will be measure in terms of the usability of the application. The usability of the application will be measure using pre-test questionnaire and post-test questionnaire. For the pre-test questionnaire, it has been answered by 20 students year 2 and the results has been shown in Figure 7 and Figure 8. The results are looking at how simple to use the application and also looking at how the application improve their understanding in data structure and algorithm concept.

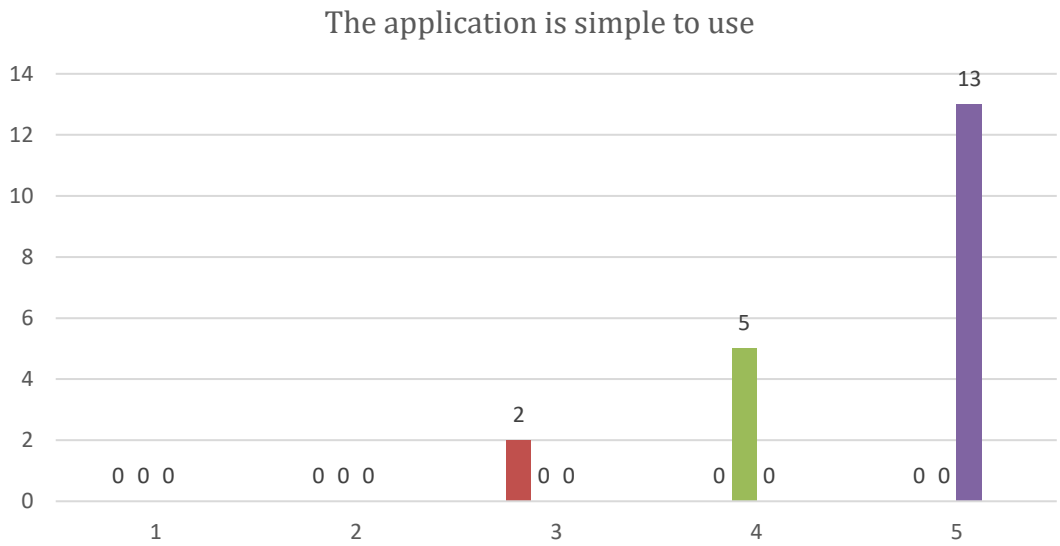

Fig. 7. The percentage of participants agree the application is simple to use

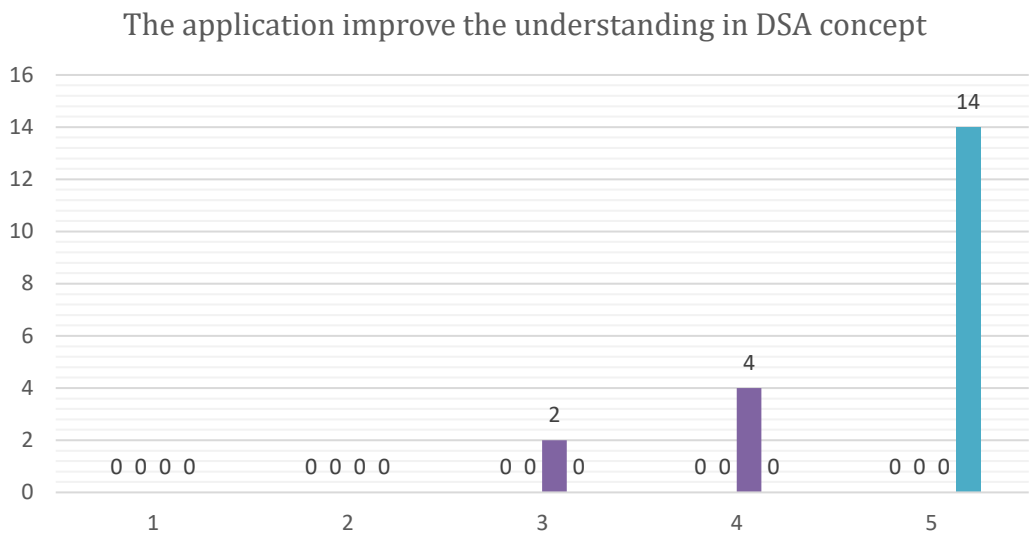

Fig. 8. The percentage of participants agree the application improve their understanding on DSA concept

For the post-test questionnaire, 80 students will be participants for the evaluation and the evaluation will be divided into two processes, before and after learn DSA in traditionally way [17]. With this method, more significance results can be generated [18]. The results of the evaluation will be explained in detail in next phase of this project after the enhancement been made for the workshop Phase 3. User acceptance testing will also be conducted once the post-questionnaire process end.

6. Conclusions

The AR technology application aims to capture students' interest, particularly when learning challenging subjects like DSA. By utilizing the AR application to learn DSA concepts, students will find the learning process more engaging and comprehensible compared to traditional classroom teaching methods. The objective of this research is to enhance the learning outcomes of DSA programming by fostering better student understanding through the utilization of the AR application. The analysis and design features of the application will cater to the students' learning needs and align with the desired outcomes of DSA education. Currently, this project is in the development phase and is expected to undergo testing and evaluation with DSA students around the end of February 2023. The specific details of the experimentation and evaluation will be elaborated upon in the forthcoming paper. Additionally, the researchers have future plans to expand the project by extending the covered topics and incorporating question creation capabilities for students as they learn DSA using the application.

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