Journal of Applied Engineering and Technological Science
Vol 6(1) 2024: 115-137

MULTIMODAL ANALYSIS OF AUGMENTED REALITY IN BASIC PROGRAMMING COURSE: INNOVATION LEARNING IN MODERN CLASSES

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Received: 18 August 2024, Revised: 29 October 2024, Accepted: 02 November 2024
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ABSTRACT
The purpose of this research was to examine the effectiveness of Augmented Reality when implemented as a modern approach in a basic programming course, to solve problems in learning abstract concepts of programming. This vision places AR as a rich solution to programming education in the digital era, given the potential of the medium in delivering a deeper understanding of programming constructs in the context of complex and engaging visualizations. In this experimental study, a multimodal analysis and the ASSURE model were used in incorporating AR in a contemporary classroom. There were 61 students who took the basic programming course for students and all of them were included in the study. Self-completed questionnaires were used to record the impact of AR on the students, specifically on the understanding of the concept, motivation to learn and learning engagement. The study brought out the following key discovery; Ar enhanced students' comprehension of the basic concepts in programming, enhanced their interest and encouraged them through the creative design of the learning process. AR enhanced some aspects of programming elucidated by student, particularly turning the complex programming strategy into an easily manageable model as well as providing for a real-time simulation and graphical rendering, all of which were difficult. Still, and importantly, AR cut down on mistakes and provided a clear understanding of the coding patterns Iraq required. Applying AR into the learning of programming education has practical implications in improving students learning experiences as well as simplifying existing concepts. In theory, this work entails the effectiveness of Augmented Reality in programming education and the exploration of opportunities for application of new ideas in technology-enabled teaching in the information age.
Keywords: *Augmented Reality, Programming Course, TVET.*

1. Introduction

Modern education continues to evolve by utilizing various advanced technologies to improve the quality of learning. One of the increasingly popular technologies is Augmented Reality (AR), which combines the real world with virtual elements to create a more interactive and immersive learning experience (Huda et al., 2021; Resch et al., 2015). As the case of programming learning has shown us, the application of AR unvain array of possibilities for integrating engaging learning approaches to the teaching-learning process that can assist students confront even abstract concepts more effectively in a more natural manner. The present study will concern the implementation of AR in programming subjects while employing a multimodal perspective to explore how the programs impact students' attitude, knowledge gain, engagement in the contemporary learning context (Resch et al., 2015).

Many educations define programming learning as complex and abstract to many students. Traditional forms of teaching, including the use of class sessions that involve the use of books and teachers' talking being the major avenue of passing over information can be inefficient in presenting abstract ideas. It therefore becomes quite challenging for several students to grasp whatever is being taught together with grabbing the interests of the lessons being taught. In recent years, there has been arising interest in the application of technology in learning with a view of overcoming these challenges (Gong et al., 2020). One such technology is the

Augmented Reality (AR) technology which can offer canned graphics of ideas that programmers have about algorithms. Despite the understanding of the capabilities of AR in learning the studies that particularly focus on the use of the concept in programming classes are scarce. As such this work shall investigate how AR could be useful as a learning tool in programming classes by multimodal analysis to determine its influence on a range of learning factors.

Given the continuously growing importance of programming education in today's world, this paper aimed to focus on how programming education can respond to such demands and improve through more appealing teaching practices (Bos et al., 2022). Traditional approaches are deemed insufficient to support the acquisition of these skills, especially since many program-related concepts are abstract and challenging for students with elemental levels of understanding (Harrington et al., 2021). AR could offer a possible solution to enhance the level of learning by making complicated concepts visible, if true this would mean that flavor of delivering programming courses would change drastically. This research is also important in the overall area of educational technology as AR can be implemented in a diverse manner to support the learning by doing concept.

Existing programming education has the following shortcomings when it comes to enabling students grasp abstract concepts that have some certain level of difficulty. Some of the main challenges are that the student is disengaged and has little motivation to learn programming, primarily because there is no good visualization tool that can help in the process (Smith, 2023). Despite attempts at utilizing several traditional approaches of teaching, they are still somewhat restrictive in terms of being able to deliver rich and sufficient learning environment, especially with the modern classes, which are more and more influenced by technology. These limitations suggest that there is little known about the satisfaction of using Augmented Reality (AR) technology for programming education in the existing literature. Indeed, AR provides the opportunity to provide abstract visualizations directly that can benefit learners when combined with timely simulations and graphical images (Ha et al., 2024). Nonetheless, the study on the use of AR in programming learning is still limited and scarce. This study intends to contribute to this scarcity by assessing how AR might be incorporated into Entry-Level programming courses fully and how it influences learners' attitude, content comprehension, and participation levels.

This is especially true in the current and growing day technological world where the knowledge of programming languages is rather important. However, traditional approaches to teaching often cannot reach the students' needs in learning styles while also failing to offer an engaging and realistic experience. AR provides an innovation in presenting information, as using programming code and algorithmic showings in 3D can be more comprehensible for students and less forgettable (Wulansari & Nabawi, 2021). Further, AR has the ability for students to have one on one contact with the content they are learning making the learning process livelier. Several studies within prior literature prove that the method of augmented reality in learning may raise the motivation and engagement of students. Nevertheless, there is knowing about the possibility of using AR in the programming courses and its learning outcomes in specific details. Hence, the present study will use a multimodal analysis of using AR in programming courses concerning the following aspects: effectiveness in training, influence on motivation and engagement of students, and implementation issues (Novalinda et al., 2023).

This research will therefore propose a way forward on the possibilities and likelihood of adopting AR in learning programming. The research instruments are classroom observation, questionnaires completed by students and teachers and students' learning achievements. The findings of this study should be relevant to educators and educational technology engineers with a view of extending enhanced, and more innovative approaches to the implementation of AR-based learning. From this study, the following is expected to be demonstrated: AR is not only visualization tool, but also an enhancement tool for interactive and collaborative participation and for the development of concepts related to learning programming. Therefore, this research will assist in enhancing the teaching approaches to teaching programming to the students to avert them facing challenges or proving difficult to learn and hence preparing them to face future challenges in the technology field (Prasetya et al., 2023; Wulansari et al., 2022).

As derived from the recent body of literature, there is a scarcity of research article on the effects of AR in systems that relate with programming education (Kaplan-Rakowski et al., 2021). This study aims to close this gap by providing quantitative data on the advantages and disadvantages of adopting AR concerning the topic under study in basic programming courses. This research can serve as the basis for improvement in the ways that programming education is taught and presented, most especially considering contemporary education and the role that AR will play in the future. This research is crucial as it can counter inabilities of the conventional teaching pedagogies in programming courses in as much as they are incapable of exploring abstractions and complicated concepts in the subject. AR is a relatively fresh approach as compared to the traditional ones and is more engaging and interactive and the three-dimensional visual enable students to grasp the concepts which are being taught easier. Further, AR can enhance the performance, interest, and participation of hard-working, but easily bored students especially when learning programming using uninteresting methods (Kwon & Morrill, 2022). Incorporation of AR based learning is thus capable of eliciting curiosity and real higher learning enthusiasm. This study will also be useful as programming skills as a necessity in the current society is on the rise, and there is a need to produce human capital with those skills. Hence, in this case, one badly requires updating and coming up with better and creative teaching techniques to assist the common student grasp programming techniques. Furthermore, this study will benefit the creation of new learning technologies since it will establish the means for applicability of AR in programming learning which will be further used for the development of more elaborate and effective apps and learning tools (Chiang et al., 2022). With AR, learners can have a feel of what they are learning, regardless of whether they are in the class physically or not. This research will seek specifics of how AR can be applied in programming education, and it is believed that the results of this study will be pertinent to other learning contexts hence benefiting the educational stakeholders, developers of educational technologies, and policy makers in designing better teaching methodologies and strategies. That is why the aim of this research is to perform multimodal analysis of AR in basic programming courses.

2. Literature Review

Design and characteristics of AR

The nature of the design and the characteristics of augmented reality (AR) indicate that this technology has a good potential to build up and develop the notions of user experience in different fields such as education and entertainment as well as industry. Great design of AR is most generally characterized by components like interaction, content appropriateness and context, and physical environment correspondents. In the study made by Kwon & Morrill (2022), he defined augmented reality as a technology that overlays the real and the virtual and allows interaction and the visualization of objects in three dimensions in real time. Of these, the most significant are Immersion and Interactivity, within which AR possesses the properties of a high degree of engagement of the user. According to Demircioglu et al. (2023), one of the key suggestions is that the interface should be timeless, engaging and should operate in real-time. However, it is crucial to point out that for the high-precision and stability of the AR content, the use of some more complex tracking technologies is required: head and hand tracking, and image recognition.

It is essential to pay attention to the aspect of what has been designed in the context of AR implementation in education to fulfill certain pedagogical criteria, for example delivering learnable content that will encourage both individual and group learning. Other research by Azuma et al. (2001) showed that AR application can enhance the learning of concepts that are hard to grasp through representation of physical 3D models and its interaction. Still, the difficulties in AR design are not limited to technological ones: hardware problems, the dependence on the internet connection, and focus on environmental objects may appear. In sum, the literature implies that to design engaging and useful AR applications, designers should consider design guidelines that relate to ergonomic interactions and provide recommendations to issues that can occur while designing for AR applications. More specifically, there is a need to follow AR's advancement to discover the additional techniques in its design to translate it into the greatest outcome in several fields, including education.

Also, based on the literature, there are other three dimensions namely technical, interaction, and user experience (UX) in the design of augmented reality (AR). Aljojo et al. (2020) argue that motivation in AR context increases user positive experience, and it enhances learning and use of AR application in the different learning environment. As for the usability aspect designers should focus on the comfort of use, the stability of visual perception, and availability. It means that AR interface design should be inclined to have a positive impact on the user ergonomics so that their eye does not get tired, or they have problems with focusing. Moreover, the allowable colors, textures, and other such factors of the design need to be incorporated in such a way that they do not obstruct the actual user experience and his or her capabilities. Radu in his view in 2014 has pointed out that one of the biggest difficulties of the AR design is the location and occlusion of the virtual objects in the way that they do not obstruct the important real environment for users.

The studies also demonstrate that the extent of AR effectiveness depends on the ways in which the technology is compliant with learning style and preference factors. For instance, Chang et al. (2011) showed that since AR incorporates the principle of learning styles, it avails the possibility of presenting the content in ways that are congruent with the learning style of the learner; for instance, for the visual learner, the information is presented in a visual way for ease of understanding, and for the kinesthetic learner, some parts that have been presented in an interactive form will be preferred. The aptitude to be flexible is one reason that AR can be a useful application for individualized learning. Besides education, AR applications in industry and marketing as well as in entertainment domains have had considerable success. From the case of AR in the industry, it applies in training, maintenance, and assembly; it offers the vision and material information in the real-time context. In entertainment AR enriches the user experience by adding and reconstructing virtual world as it is seen in apps letting the user play AR games or use social networks (Syahril et al., 2022; Waskito et al., 2023; Wulansari, Dewi, et al., 2023; Wulansari, Marta, et al., 2023).

However, there are still some issues that should be solved to increase the possibilities of AR using. These are the development and implementation costs, the hardware requirement for such systems, and patient privacy and data security issues. Further, realization of wide-spread utilization of AR needs improved acquaintance and comprehension of its uses and effects by the everyday users and the decision-makers. In general, the available literature on design and characteristics of augmented reality reflects a definite potential of this technology to transform numerous areas of human activity and provide user with more engaging and engaging experience. Nevertheless, for the desired effects to be fully realized, they must be integrated in designs that would incorporate the technical, ergonomic, and users' aspects and certain never-ending attempts to overcome hurdles. More research and development in this area will go a long way in increasing the efficiency in the use of AR and made sure this technology can be adapted in our daily households and almost all fields of industry.

AR in Education

In this study, AR has been used across the disciplines to enhance performance of students. AR has been shown to enhance science and mathematics learning through facilitating conversion of complex concepts into real and tangible objects, enhancing learning motivation, and improving students' learning activities. A handful of previous studies suggest that AR can support understanding of abstractions by engaging learners into a more pertinent and dynamic kind of learning (Li et al., 2020). Nevertheless, these works have been predominantly concerned with the effect of AR in science and mathematics learning, while only a few works have unveiled its influence in programming education, specifically for students in tertiary institutions.

Consequently, following the literature review, there is a research gap pertaining to the effectiveness of AR in improving student achievement specifically in programming courses over a period and there is also gap concerning the features of AR application in creating enhanced programming learning. Almost all the existing research works concerns with Science and Mathematics; the role of AR in programming learning therefore lacks substantiation (Zhao

& Wang, 2022). Moreover, earlier research has still not attempted to use activity logs or interaction analysis for assessing AR-based learning processes, and thus the prospect for employing interaction data remains uncharted. Many of the prior works have shortcomings including Shortage of samples, little follow-up research, and limited generalizability of findings to a diverse sample. For instance, the advantages of application of AR in the visualization of objects in learning the sciences but overlooked the issues of technique involved in the process. A comparison of studies also reveals the conflict about the effectivity of AR in the academic setting; it is observed that students are more engaged or there is no positive impact on learning outcomes of students (Smith, 2023). Therefore, this study is aimed to close this gap by offering wider quantitative data and interactional understanding of the applicability of AR in programming education.

Challenges in AR Implementation

Nonetheless, like with any innovative tool, there are several obstacles to the adoption of augmented reality into the education system. The main challenges include technical factors, appropriate infrastructure, and the teachers' preparedness level for embracing this technology (Zhao & Wang, 2022). According to Choi & Saeedifard (2012), mounting evidence has revealed that critical factors such as how guidelines on the implementation of AR are lacking and restrictions on teacher training impede the applicability of AR in education. Consequently, the sample size is another issue, and there is also no long-term research in AR studies, and this means that the impact of using AR on the learning outcomes of students remains unknown.

This research is grounded on constructivism theory that frowns on the traditional process of learning and teaching that involves the use classroom desks and chairs. When applied in programming education, AR can be used as a motivator to suggest problems and build logical thinking by directly operating objects. This theory will help to justify the effectiveness of using AR in creating improved engagement as well as improved concept understanding in students. This literature review underlines that, while AR has a huge potential of enhancing the learning achievements of the students, particularly developers, there are only a few scholarly studies on its deployment and its consequences. Therefore, this study seeks to fill this research gap by establishing the effectiveness of AR in teaching programming skills and identify the difficulties that may hinder its use from a literature standpoint that is expected to advance knowledge in educational technology (Loughlin, 1992).

AR integrated case in basic programming course

Incorporation of augmented reality (AR) in basic programming courses give a hint that this technology is very appropriate in helping students and improving the way they learn. AR enables representation of concepts and ideas such as data structures and Algorithms for ease of understanding by the students in a three-dimensional format. Bower, Howe, et al. (2014) study come with the assertion that AR can offer a richer learning environment as compared to a traditional learning environment; this may of course lead to enhanced student engagement and motivation. According to the study done by Hedberg et al. (2018) the use of AR in relation to programming learning enables learning that which normal teaching fails to by presenting the concept in a form that the students can handle and practice on. Furthermore, AR can enhance the formation of collaboration learning in programming classes. According to the research done by (Bower, McCredie, et al. (2014), attained that due to AR, students can collaborate in the solving of programming problems and consequently enhances in social contact and cooperation proficiency. AR can also offer instant response, which is peculiar to programming learning; it enables students to see the effects of codes written by them and rectify mistakes at the same time.

However, there are several constraints when it comes to integration of AR in programming classes for instance lack of enough hardware to support the technology and lack of relevant content in supporting of programming classes. Based on the analysis made by Fortuna et al. (2023), the issues that remain vital in preventing the widespread use of AR in education are technical issues and expansion costs. Therefore, training of teachers to incorporate this type of technology in their curriculums is also important. In aggregate, current research indicates that the incorporation of AR into basic programming courses can enhance the student's comprehension and interest, as well as facilitate collaborative learning. But to reap these optimum gains, there is needed some efforts including solving of technical and costing difficulties besides teachers' training on the use of this technology. Only through further development of the technology, AR can act as an additive carried out to programming education to make the learning process even more engaging, realistic and efficient.

As for the other advantages that have not been mentioned above, the use of AR in programming learning will help to develop such skills as critical thinking and problem solving. Through AR, a student can visualize the code that they write and how, with slight variation, the algorithm runs. According to the work of Chen & Tsai (2012b), it is established that AR assists the learning of programming logic and the interconnection of objects in the programming environment. AR can also complement and enhance the approaches to teaching by making several kinds of interactions that cannot be gained through the existing learning media. For instance, AR can be employed in development of scenarios where students practice, with code, in a secure learning Hincapie et al. (2011) environment. Chen & Tsai (2012b) identified that since AR integrates the real and virtual environments, the additional element in AR creates facilitate the more all-round and contextual style of learning.

However, for utilizing AR most effectively for learning programming, content must be designed as well as chosen relevant to the curriculum. Researchers maintaining that synergy of stakeholders involved in the development of technology and educators is a prerequisite for designing highly effective AR applications that enhance learning outcomes (Chen & Tsai, 2012a). However, the study by Alalwan et al. (2020) confirms the opinion that GUI is a critical factor of effective AR interface, which must be smoothly designed and to react adequately. Concern arising from the necessity for review and assessment of the roles of AR within learning. Hedberg et al. (2018) assert that while the use of AR has been found effective in most of these studies, more research is required to establish the effectiveness of AR on students' performance after a longer period besides identifying how the use of this technology can be mainstreamed in the education system. In summary, based on the idea of using AR in basic programming courses, there are many advantages to share: it can enhance the comprehension, participation, and problem-solving skills of students. But the necessary conditions for the implementation of AR are technical and pedagogical issues as well as development of appropriate content and preparation of teachers. In my academic year of practice with these challenges coupled with further research to determine the strengths, weaknesses, opportunities, and threats of implementing AR in teaching and learning of programming it is evident that it has the potential of elevating learning to the next level of effectiveness.

3. Research Methods

Research Type

This research will apply the multimodal analysis method to measure the efficacy of utilizing AR in basic programming classes. This approach entails the use of different methods of data collection and analysis to get a holistic approach to the effects of AR on learning programming. First, the research design will use the ASSURE model to develop the AR tool, then a quasi-experimental method with two groups: an experimental group in which learning is done through AR and a control group learning through the standard methods. Target participants will include students taking the basic programming course at Universitas Negeri Padang and they will be 61 in number. Both groups will have similar lessons, and hereafter referred to as control and experimental group respectively but with the extra AR materials targeted at helping in explaining programming concepts.

Research Sample

This study sample comprised 61 students studying at Padang State University who took the basic programming course in Informatics Engineering study program. Respondents were recruited purposively based on their previous programming experience, as this study involved working with program files. The selected students were beginners; they have not many semesters or experiences, thus applying AR can enable the students to gain proper understanding of programming. The sample of the participants was made up of 18–21-year-old students with little prior knowledge in programming logic. Other test that was conducted in the analysis of sample size was aimed at establishing whether the number of participants for the study was adequate in producing enough outcome. For this research, a minimum of 61 students was found to be sufficient with 95% confidence level and 5% margin of error.

Research Procedures

The method to be used in this study is the ASSURE procedure: analyze learners, state standards and objectives, select media and materials, utilize media and materials, require learner participation, evaluate and revise to ensure that, the incorporation of augmented reality (AR) in the basic programming course is implemented properly. First, in the Analyze Learners stage, student information will be examined as to their background, their learning capacity, and most importantly, their programming competency as students. The surveys and the first interviews will be used to gather demographic information, education, learning and motivation profiles. This information will assist in development of AR materials that are in harmony with the students' learning ability.

Also, at the State Standards and Objectives stage, the learning objectives will be described precisely and distinct. These objectives include the programming skills which the students are supposed to acquire and how AR is going to aid in the achievement of these objectives. The objectives formulated will align with curriculum standards and will center on knowledge of programming concepts; skills; and problem-solving. The last of these is the Select Media and Materials where the right media and materials that should be used in achieving the said objectives are identified. For the scope of this research the primary media to be chosen is an AR app for programming concepts' demonstration. Other, including learning modules, video tutorials, and the guidebooks will also be selected to accompany the use of AR.

During this learning-teaching process, the media and materials, which were selected in the final stage of the development of learning-teaching complex, will be utilized. Lecturers will be trained with application of AR and incorporate them in the delivery of traditional lectures. Instructional activities that incorporate the use of augmented reality will need to be created and include demonstrations, progressively complex learning activities as well as quiz-like activities to check on students' comprehension. The Require Learner Participation stage checks that students are engaged in the whole learning process. The use of AR in learning sessions will be in form of brainstorming, group activities, and one-AR-learning projects. Students will be free to navigate through the AR application, engage with the content and subsequently convey information on the experimental process with their counterparts. Last but not the least, at the last stage that is the last cell of the table, the extent and utility of using AR in learning will be assessed. The results of the study will be used as a basis of comparison to determine if the learning objectives have been met: Qualitative: Quantitative: The assessment in this evaluation includes pre-test and post-test, satisfaction survey, and interviews as well as classroom observation. Therefore, working based on the results of the evaluation shown in this study, certain modifications will be recommended to optimize and amplify the application of AR in learning basic programming. Such changes may be made to the AR content and the strategies used in teaching, or the assessment instruments employed.

Then pretest and posttest will be conducted for getting the quantitative data to determine the enhancement of the students' knowledge and programming abilities. Further, expected method incorporates survey and questionnaires to determine the learning experience, the level of engagement as well as the satisfaction of students concerning the incorporation of AR. All these data will be subjected to a test of descriptive and inferential to ascertain the extent of the differences between the experimental and the control group. As it will be impossible to get qualitative data through questionnaires, qualitative data shall be collected through interviews with students and teachers besides observations in class. These interviews shall question student's perception and experience on the use of AR, perceived risks and gains. The monitoring of the classroom will assist in the observation of dynamics of student interaction and collaboration during learning sessions with AR. In case of qualitative data, narratives and opinions, thematic analysis will be employed in a bid to categorize the data and develop themes and patterns.

Second, the investigation of screen recordings and self-generated notes by the students when utilizing the AR app will be affected to determine the engagement of the learners with the technology, and the impact of this engagement on their learning. The details obtained from these recordings will be extracted with interaction analysis and other data visualization methods to reveal the learnt techniques and issues of students. Conducting both quantitative and qualitative research means, it is believed that this study will be able to make a significant discovery about the extents to which and how AR can be used in basic programming learning. In turn, the outcome of this study will be an invaluable addition to the advancement of educational technology and teaching method in an era characterized by the internet.

ASSURE Model in AR Instructional Design

For this purpose, the primary method of instruction for implementing Augmented Reality was selected in the form of the already mentioned ASSURE model, aimed at making the students' learning process effective and conducive to their characteristics as well as learning outcomes. The ASSURE model consists of six stages, and the following is an explanation of the operationalization of each stage in the context of this study:

Learner Analysis. Learner analysis was performed to determine essential characteristics and requirements of students regarding realizing basic programming concepts. Consequently, the analysis of the results has established that the most of students try to find explanations of basic programming logic and would like to have clear diagrams. Drawing from findings made above, AR content was created to present easily understandable visual representations such as Program logic flows, basic programming structures among others, to ensure that the content augments the need for programming learning; Writing Learning Outcomes. The learning goals of this lesson are as follows: To enhance the students' knowledge regarding various programming manipulations such as the logic flow and control structures like loops as well as branches and to increase students' motivation. Thus, with the help of AR, it is predicted that the learning is going 'to be more effective and help the users understand complex information through the use of the application 'guns'; Selection of Methods, Media and Materials. AR was selected to be the primary media due to its characteristic of adding both visual and interactive functions, which can support students' understanding of abstract knowledge. The developed materials include augmented reality simulations to explain fundamentals of programming such as looping and branching logic. This content is designed to follow multimodal approach to support text, graphics and audio that can help the students grasp better concepts.

Use of Media and Materials. The use of AR is in the teaching–learning processes during learning sessions when students use mobile devices or tablets as the application platform to access AR content. Every AR simulation is designed to involve one topic from basic programming and the process is broken down step by step so that students can see the programming process as they manipulate the objects they are simulating, top to bottom; Learner Participation. Such engagement is expected of learners through direct interaction with the AR simulation. Individual and grouped assignments based on cases are solved by students independently using AR. This direct interaction is meant to develop problem solving skills and enable the students realize practical scenarios in which programming concepts can be utilized; Evaluation and Revision. Assessment includes plenty of questionnaires and quizzes of a formative nature in order to assess the knowledge retention of the students, their learning attitudes, and engagement, respectively. Therefore, in case of low learning effectiveness, changes to the material or the approach can be made according to the evaluation results.

Multimodal Analysis Method

Multi-modal analysis techniques are applied to determine how, in relation to visual, textual and audio AR content, the programming learning process can be enhanced. This analysis conforms with the research objective of assessing the degree to which the combination of several forms of modality enhances students' learning processes. It is much easier to use this method to review the student's involvement with AR content in more detail, such as activity history, observation of visual response, and more the students' participation during the learning process.

Instruments of system usability, user experience and error rate in coding tasks

It is justified to mention that there are three instruments that allow the assessment of system usability, user experience, and error rate in programming tasks to investigate the impact of using augmented reality (AR). For the determination of the system usability, the primary tool applied is called System Usability Scale (SUS). SUS is a 10-item standardized self-administered questionnaire developed to assess the user-freedom ease of use of a system based on 5-point Likert scale comprising of 'strongly disagree,' 'disagree,' 'neutral,' 'agree' and 'strongly agree.' To this end, the following points are gauged are includes usability, learnability and satisfaction. Given by SUS, a quantitative measure is assigned to compare and or make a usability analysis of the AR systems and normal learning systems.

The User Experience Questionnaire (UEQ) instrument is used to assess the User Experience. Although UEQ is a measurement instrument of the technical quality of user experience, it includes six dimensions: attractiveness, clarity, efficiency, accuracy, stimulation, and novelty. There are 26 questions in this questionnaire and the semantic differential scale is used, whereas the users get an opportunity to deliver a richer description of their experience when using AR applications. Collected data from the UEQ will be again used to understand how effective and ineffective the AR app is in developing a positive learning experience. In the case of programming tasks, activity log analysis and screen recordings are applied in the assessment of the error rate. The activity log will capture the action being made by the students while using the AR app not forgetting the errors made and the time taken to accomplish the task. Further, screen recordings will be employed in order capture how students engage with it as well as common mistakes made by the subjects. Errors will be defined broadly, and this will entail putting them into different classes, which include syntax errors, logic errors and compilation errors. This information will then be used to determine the number and kinds of mistakes as well as to determine areas of greatest difficulty for students.

Pilot Study

To test reliability and validity of the instruments used to measure usability of the system and the level of experience and error frequency of the subjects when programming, a pilot study will be carried out. Thus, this pilot study will try to make sure that only valid and reliable data can be gathered from the instruments to be employed in the actual study and, at the same time, will seek out and eliminate possible flaws that may be encountered in the actual operation of the research. In a summarizing manner, the pilot study will present some advantages and the scopes in the reliability and validity of the instruments that will be employed in the main study. As a result of these initial trials, researchers can also determine from the instruments the level of system usability, user experience, and the rate of errors that can be expected when the system is fully deployed. The findings of the pilot study will also give a good pilot for data analysis in the main study therefore enhancing the credibility and validity of the research.

First, with purpose of evaluate the reliability of instrument, the SUS's pilot test will be taken to a small group of students on the course. For learning Basic programming, the students will use the augmented reality (AR) application which has been created. They will be requested to fill SUS questionnaire after the usage session they have with the interface. To ensure that an enlightened sentiment has been accorded by the respondent to the items on the questionnaire and that there is a high reliability of the measuring instrument, the above collected data shall be subjected to analysis. Furthermore, responses derived from students will be used to make changes to the questions that are ambiguous, or lacking in relevance to the questionnaire format if needs be. The same will apply to the User Experience Questionnaire (UEQ), which, too, shall be validated. The same students will be asked to complete UEQ questionnaire after they interacted with the developed AR application. Analysis will also be made on the collected data to establish the reliability and validity of the questionnaire in this perspective. Surveys will also be given to students to listen back from them whether the specific UEQ's semantic differential scales fit their experience and whether they can measure different aspects of user experience.

Thus, using the activity logs and screen recordings, the error rates in programming tasks will be determined. Students will be required to perform several programming tasks through an AR application and the performance will be captured to observe mistakes that are made. This pilot study will help in identifying the relevant error categories and facilitated error recording and analysis so that it will be conducted proficiently and competently. The results obtained from the pilot study will be used to enhance the error rate measurement instrument for instance by increasing the accuracy of error categories and the method used in recording activities.

Data Analysis Technique

The data analysis technique for this research is quantitative to arrive at an estimation and generalizability of the extent of using augmented reality (AR) for learning programming. Coded data will be analyzed by descriptive and inferential statistics. Assessment will be made using pre-test and post-test to be used in evaluating the extent of perceived students' programming understanding and skills with and without AR. Frequency and distribution analysis: frequency tables and distribution analysis will be employed a way of describing basic data with special focus on the mean median and standard deviation. Meanwhile, inferential statistics including independent t-test and ANCOVA test shall be used to compare the results of the experimental group with the control results. Furthermore, linear regression may be used to determine characteristics that affect the students learning outcomes.

Furthermore, all screen recordings and the activity logs of the students about the usage of the AR app will be subjected to regression analysis and data visualization. This paper seeks to look if and how students engage the AR technology in question and consequently, how this engagement influences their learning process. The interaction data will be analyzed using coding technique to reveal the learning approach, the challenges faced and the usage profile of AR App. In more detail, the data analysis methods of this study aim at offering a multifaceted assessment of the effectiveness of AR in learning programming by examining a broad range of stakeholders' learning processes and outcomes. With this combination of analytical facilities, the research should provide a meaningful impact to the field of educational technology and teaching methodologies in the age of the technologies.

4. Results and Discussions

System Usability

In this research however, system usability is centered on measuring the ease of use of augmented reality (AR) apps that have been incorporated in the basic programming learning. Measuring user perceptions with the SUS scale, this research focuses on the overall perception of usability with reference to learnability, efficiency, and satisfaction.

Table 1 - Perception of Usability Indicator

Code	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	Total	Mean	SD	SR (%)
US01	50 (81.97%)	5 (8.20%)	4 (6.56%)	1 (1.64%)	1 (1.64%)	61	57	108.17	93.44
US02	42 (68.85%)	12 (19.67%)	4 (6.56%)	2 (3.28%)	1 (1.64%)	61	55	88.66	90.16
US03	53 (86.89%)	7 (11.48%)	0 (0%)	1 (1.64%)	0 (0%)	61	59	115.77	96.72
US04	52 (85.52%)	9 (14.75%)	0 (0%)	0 (0%)	0 (0%)	61	59.2	113.33	97.05
US05	48 (78.69%)	10 (16.39%)	3 (4.92%)	0 (0%)	0 (0%)	61	57.8	103.17	94.75
US06	55 (90.16%)	5 (8.20%)	1 (1.64%)	0 (0%)	0 (0%)	61	59.6	120.70	97.70
US07	45 (73.77%)	12 (19.67%)	1 (1.64%)	2 (3.28%)	1 (1.64%)	61	56.2	96.39	92.13
US08	56 (91.80%)	5 (8.20%)	0 (0%)	0 (0%)	0 (0%)	61	60	123.29	98.36
US09	43 (70.49%)	11 (18.03%)	7 (11.48%)	0 (0%)	0 (0%)	61	56	90.72	91.80

US10	56 (91.80%)	5 (8.20%)	0 (0%)	0 (0%)	0 (0%)	61	60	123.29	98.36
US11	54 (88.52%)	7 (11.48%)	0 (0%)	0 (0%)	0 (0%)	61	59.6	118.24	97.70
US12	46 (75.41%)	10 (16.39%)	1 (1.64%)	3 (4.92%)	1 (1.64%)	61	56	98.57	91.80
US13	47 (77.05%)	14 (22.95%)	0 (0%)	0 (0%)	0 (0%)	61	58.2	101.77	95.41
Average of SR									95.03

Considering the findings shown in Table 1, the mean for all the efficacy indicators of usability assessment items was 95. 03%%. From these results, all the usability of AR adopted by teachers in learning and the assessment conditions of the usability of AR obtained from the survey conforms well with the following: Thus, points obtained from the data analysis of SUS questionnaire indicates that the AR application is highly usable, and users do not find difficulties in using this application. Students mentioned that the use of AR application enhanced the clarity of the ideas in via the technological interactivity of the programs as a way of enhancing the overall comprehension of the programming concepts amongst the students. Besides, navigational convenience and understanding the idea of the site's design also contributed to the positive user experience.

Table 2 - Perception of Convenience Indicator

Code	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	Total	Mean	SD	SR (%)
CN01	56 (91.80%)	4 (6.56%)	1 (1.64%)	0 (0%)	0 (0%)	61	59.8	123.27	98.0
CN02	54 (88.52%)	7 (11.48%)	0 (0%)	0 (0%)	0 (0%)	61	59.6	118.24	97.7
CN03	33 (54.10%)	24 (39.34%)	0 (0%)	0 (0%)	4 (6.56%)	61	53	74.85	86.9
CN04	54 (88.52%)	5 (8.20%)	0 (0%)	1 (1.64%)	1 (1.64%)	61	58.6	118.46	96.1
CN05	46 (75.41%)	7 (11.48%)	5 (8.20%)	2 (3.28%)	1 (1.64%)	61	55.6	98.07	91.1
CN06	54 (88.52%)	7 (11.48%)	0 (0%)	0 (0%)	0 (0%)	61	55.6	98.07	455.7
CN07	32 (52.46%)	29 (47.54%)	0 (0%)	0 (0%)	0 (0%)	61	59.6	118.24	488.5
CN08	58 (95.08%)	3 (4.92%)	0 (0%)	0 (0%)	0 (0%)	61	55.2	77.17	452.5
CN09	49 (80.33%)	4 (6.56%)	6 (9.84%)	1 (1.64%)	1 (1.64%)	61	60.4	128.46	495.1
CN10	54 (88.52%)	7 (11.48%)	0 (0%)	0 (0%)	0 (0%)	61	56.4	105.72	462.3
CN11	45 (73.77%)	9 (14.75%)	4 (6.56%)	1 (1.64%)	2 (3.28%)	61	59.6	118.24	488.5
Average of SR									94.7

From Table 2, the mean scale points of all the items from the convenience assessment indicator are 94. 7%%. These results imply that the requirements for convenience of AR used by educators in learning and the assessment conditions on the convenience of AR derived from the survey data have received good satisfaction. Although there some are challenges that we have been able to identify. Many of the users noted that the app was intuitive, while a few of the students said that they had experienced certain technical problems, e.g., issues with the speed, or compatibility with the used devices. It was useful for further enhancement of the application and to enhance its responsiveness of the application and compatibility to the devices the students use.

Table 3 - Perception of Efficiency Indicator

Code	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	Total	Mean	SD	SR (%)
EF01	54 (88.52%)	3 (4.92%)	1 (1.64%)	3 (4.92%)	0 (0%)	61	58.2	118.48	95.4
EF02	57 (93.44%)	2 (3.28%)	0 (0%)	1 (1.64%)	1 (1.64%)	61	59.2	126.26	97.0
EF03	55 (90.16%)	6 (9.84%)	0 (0%)	0 (0%)	0 (0%)	61	59.8	120.75	98.0
EF04	44 (72.13%)	10 (16.39%)	2 (3.28%)	2 (3.28%)	3 (4.92%)	61	54.6	93.75	89.5
EF05	38 (62.30%)	17 (27.87%)	2 (3.28%)	4 (6.56%)	0 (0%)	61	54.4	80.66	89.2
EF06	58 (95.08%)	3 (4.92%)	0 (0%)	0 (0%)	0 (0%)	61	60.4	128.46	99.0
EF07	52 (85.25%)	2 (3.28%)	7 (11.48%)	0 (0%)	0 (0%)	61	57.8	113.36	94.8
EF08	58 (95.08%)	2 (3.28%)	1 (1.64%)	0 (0%)	0 (0%)	61	60.2	128.50	98.7
EF09	39 (63.93%)	14 (22.95%)	8 (13.11%)	0 (0%)	0 (0%)	61	55	81.57	90.2
EF10	57 (93.44%)	4 (6.56%)	0 (0%)	0 (0%)	0 (0%)	61	60.2	125.86	98.7
EF11	47 (77.05%)	11 (18.03%)	0 (0%)	0 (0%)	3 (4.92%)	61	56.4	101.57	92.5
EF12	39 (63.93%)	18 (29.51%)	1 (1.64%)	3 (4.92%)	0 (0%)	61	55.2	83.69	90.5
Average of SR									94.5

From table 3, the average scale points of all the items under the efficiency assessment indicator is 94. 5%%. These results show that educators' learning/assessment conditions using AR have been achieved to a good extent and the efficiency conditions of the AR developed from survey data are reasonable. The rationale of embracing augmented reality (AR) in learning is brought out by several elements that enhance learning and teaching. AR makes it possible that what is often difficult to be depicted in an easy and real way is depicted and student's learning process is facilitated in the sense that students can grasp easily things that are taught. Programming learning by using AR can give the students the real-time and interactive results of the program they are developing, which shorten the time in analyzing and fixing the discrepancies. Due to presenting the learning environment in the augmented reality mode, learners are more motivated and interested in learning new materials.

Table 4 - Perception of Satisfaction Indicator

Code	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	Total	Mean	SD	SR (%)
ST01	49 (80.33%)	9 (14.75%)	0 (0%)	3 (4.92%)	0 (0%)	61	57.4	105.93	94.1
ST02	53 (86.89%)	8 (13.11%)	0 (0%)	0 (0%)	0 (0%)	61	59.4	115.77	97.4
ST03	45 (73.77%)	9 (14.75%)	7 (11.48%)	0 (0%)	0 (0%)	61	56.4	95.47	92.5
ST04	43 (70.49%)	11 (18.03%)	0 (0%)	7 (11.48%)	0 (0%)	61	54.6	91.45	89.5
ST05	45 (73.77%)	11 (18.03%)	0 (0%)	4 (6.56%)	1 (1.64%)	61	55.6	96.40	91.1
ST06	52 (82.25%)	9 (14.75%)	0 (0%)	0 (0%)	0 (0%)	61	59.2	113.33	97.0
ST07	56 (91.80%)	3 (4.92%)	1 (1.64%)	1 (1.64%)	0 (0%)	61	59.4	123.41	97.4
ST08	45	11	0	0	0	61	57.8	97.49	94.8

	(73.77%)	(18.03%)	(0%)	(0%)	(0%)				
ST09	53 (86.89%)	6 (9.84%)	0 (0%)	0 (0%)	2 (3.28%)	61	58.2	116.05	95.4
ST10	56 (91.80%)	5 (8.20%)	0 (0%)	0 (0%)	0 (0%)	61	60	123.29	98.4
ST11	55 (90.16%)	6 (9.84%)	0 (0%)	0 (0%)	0 (0%)	61	59.8	120.75	98.0
				Average of SR					95.1

The findings from the analysis of the satisfaction assessment indicator are summarized in table 4 below, whereby the average scale points for all the items are 95. 1%%. The above results suggest that the set of satisfaction of AR used in learning and the conditions for assessment of satisfaction of AR received from survey data have been met. This comparison also showed that the subjects of the experimental group, who completed the AR, reported higher level of satisfaction with the learning process than the control group who has been learning through conventional methods. This implies that integration of AR is effective not only in enhancing mastery of knowledge, but also in the provision of fun in learning. Therefore, the discussion also encompasses the future work and implementation of AR technology in education based on the given findings. AR can be a very useful learning paradigm when used correctly and where its learning objective is well aligned with the course subject matter such as when the course entails visual representation such as programming. So, it is claimed that the elimination of technical issues and the steady enhancement of the application's performance can make AR an essential part of the educational curriculum in the future. In general, they highlight several aspects of usability as a critical factor in utilization of new technologies in education. The study demonstrates that when the creators of AR applications consider usability and user requirements this kind of technologies has a powerful impact on the learning process and students' achievements. This evaluation would be helpful to educational technology developers or teachers desiring to include AR in their learning.

Table 5 - ANCOVA Analysis Result of System Usability

Source	df	Mean square	F	p	η^2
Pretest	1	135.355	17.762	0.000	0.181
Group	1	1676.353	18.409	0.000	0.156
Error	58	77.353			
Total	61				

Table 5, test for the analysis of covariance indicated that the experimental group mean score was significantly higher than the control group in the use of media technology in learning, F (l, 58) = 18. 409, p < 0. 05, η2=0. 156). This effect size is the eta-squared with a value of 0 being qualified as a small effect size. 01, a medium effect of it has a value of 0. fluence if the coefficient estimate has a value of 06 and a large influence if the coefficient has a value of 0. 14. The ANOVA analysis of this study gives a value of η2 = 0. 156, which can be considered as a significant effect size as per the Cohen's criteria. In general, the findings of this study imply that with the help of a good usability system augmented reality can enhance the students' abilities compared to the traditional learning approaches. A study by Chiang et al. (2022) that assessed the integration of AR in learning of science revealed that the use of AR technology enhanced the learning achievements and interest of the learners as was the case in this research. Nevertheless, the study did haven't more coverage of the cognitive results and lack deeper analysis on the usability aspect. They pointed out that while using of AR positively influenced comprehension several students trapped in the intricate interface of AR. This is supporting with the study's findings where some of the students also complained of technical challenges including page delay and incompatibility with some devices, they use to access the learning platform. Different is research of Saidin et al. (2015) focused on the use of AR in mathematics learning, the results showed that while AR applications enhanced the understanding of concepts significantly, the usability scores were low. From this work, it is evident that consumers consider AR applications as complicated and not very easy to use. However, more usability testing in this study yielded relatively high usability scores where the students perceive that the use of AR app supports their understanding of programming concepts than using a text-based instruction on the courseware and the interface of the AR app is easier to use. This suggests improvements in the design of AR apps, which may reflect technological advancements and a better user experience.

According to Dunleavy et al. (2009) study about the usability of AR in language learning environment, the author identified that while the use of AR applications engages the students more, problems such as response time and system stability are always on the spotlight. These findings are like this study where technical barriers that include compatibility of devices and loading time is still a hindrance, albeit the increase in usability scores and satisfaction among users. In general, comparing with previously conducted studies, it is possible to define the idea that the utilization of AR within learning is gradually growing, and the usability is being increased substantially, but there are definite technical issues, which must be solved to enhance the efficiency of the specified technology. Using K-S experiment, this research contributes to the existing literature on how AR can be used to support learning of programming by demonstrating that better design of the application and paying attention to the low-level specifications of the application yields better experience than in previous studies. The findings also involve the idea of enhancing the facility of the technology to fit the users and enable them to learn effectively.

In addition to this, the following are some of the aspects that have surprised while conducting the study although they may not have been revealed by other similar studies. For instance, a study by Chiang et al. (2022) on the application of AR in engineering learning and teaching found out that although this technology enhances content visualization and comprehension, little is said about how AR can enhance students' collaboration. The author of this study concluded that it was effective in enhancing understanding not just by the individual but also by elicits group interaction among the students as they discuss on their observations and experiences on its application of the AR application. This is indicative of the possibility of AR in enhancing collaborative learning and this speaks well for it as most of the earlier studies point more to individual learning. Moreover, in the study of Kwon & Morrill (2022) who focused on the views of the key stakeholders on the use of AR in medical education, the authors pointed out that the last mentioned is closely related to the requirement of expensive and hard-to-access hardware. For this study, it has equally been realized that the developed AR apps can equally support the standard and affordable devices that include smartphones and tablets. This implies that there is a gradual improvement in the level of openness of AR technology, meaning that nowadays more and more educational units can apply and use this technology without using significant funds to buy specific equipment.

This research also provides a richer perspective as to what learning with AR is like. For example, Demircioglu et al. (2023) study on the AR in enhancing students' learning of physics revealed enhanced students' engagement but failed to capture and analyze the detailed influence of AR on students' emotional and motivational responses. In this study, in addition to finding out the usability and cognitive learning preferences, other preferences such as learning motivation preference were found to have increased among students using AR as the medium of learning and the learning process being fun filled. This indicates that apart from being an instrument for learning by enhancing the cognitive abilities of a particular subject, AR can also be used to enhance the interest and hence the learning motivation of students. Therefore, inferencing from these differences, it could be deduced that this research has offered a significant contribution in determining the feasibility of AR in enhancing basic programming learning. They learn and show that areas which are good designed, and which consider the needs of the user have a positive influence on the learning experience and state that the solution of last technical problems is decisive for success. Based on the quantitative and qualitative data collected, this research presents real quality and quantity compared to previous studies and can include more precise suggestions that can be focused on the future advancement of the AR in teaching and learning.

User Experience

User experiences in this study focuses on evaluating students' experience when using augmented reality (AR) applications in basic programming learning. Using the User Experience

Questionnaire (UEQ), this research measures various aspects of user experience, including attractiveness, clarity, efficiency, accuracy, stimulation, and novelty.

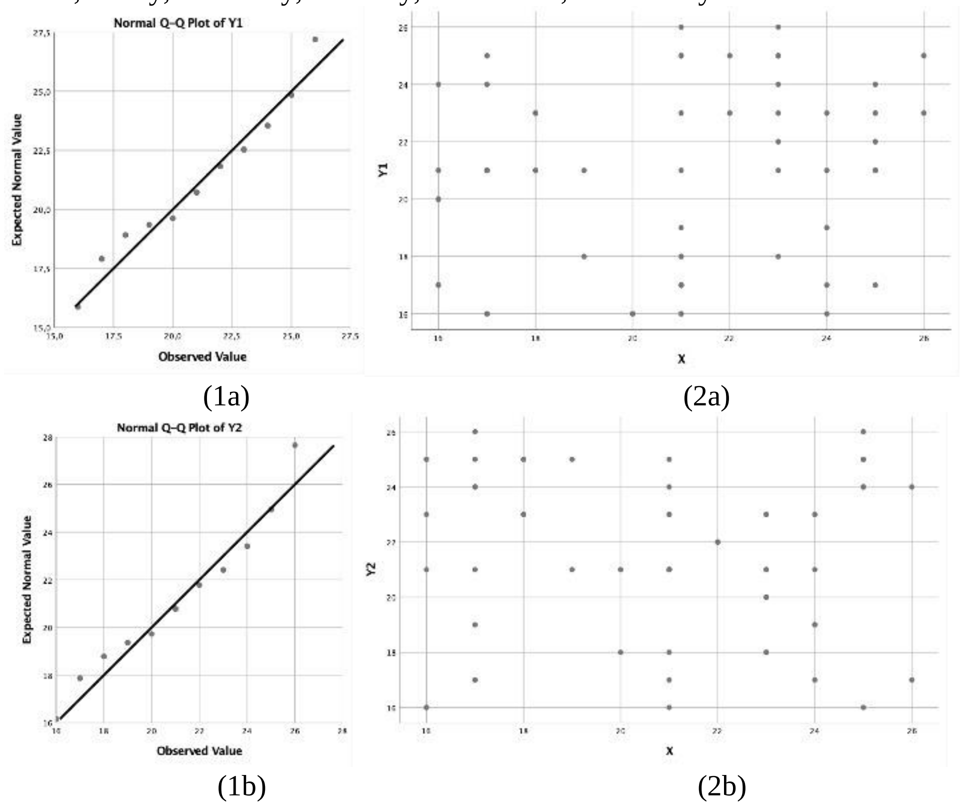


Fig. 1. Normality Test QQ Plots (1) and Linearity Scatter Plots (2) of Control (a) and Treated Groups (b)

The normality of the data distribution was tested using Shapiro-Wilk. The distribution of the post-test mean scores of the control group tests was not statistically significantly different from the normal population [$p > 0.05$, W = 82.97]. The distribution of post-test mean scores of the experimental group also did not differ statistically significantly from the normal population [$p > 0.05$, W = 675.23]. So based on the normality test (Figure 1) it is found that both groups fall into the normal category, this is also evident from the data that is evenly distributed on the line in the center of the curve. So that the data can be continued to carry out parametric tests, namely the t-test.

Table 6 - T-test Analysis Result of Control and Treated Groups

Observations	Groups	Paired Sample T-test	
		Mean	t-test
Pretest-Posttest analysis	Experimental	μ = 82.5	t(29) = 13.554; p = 0.000
	Control	μ = 68.3	t(28) = 2.356; p = 0.320
			Independent Sample T-test
Post-test comparison analysis		Mean	t-test
	Experimental	μ = 82.79	t(57) = 12.735; p = 0.000
	Control	μ = 66.41	

Table 6 shows a significant difference in students' skills between the experimental and control groups [df=49, t=12.735, p-value=0.00, p<0.05]. That is, the experimental group outperformed the control group in terms of skill improvement after the use of AR. As a result, the impact of the treatment was seen in the posttest score after the experimental group applied AR. This can be seen from the p value, if the p value is smaller than 0.05. Students reported that the AR application made learning more interesting and fun, increasing their motivation to learn programming. The interactive visualizations provided by the AR app helped students understand difficult concepts in a more intuitive and engaging way. The novelty aspect also scored high, indicating that the use of AR technology provides a fresh and innovative learning experience for students. But there are slight concerns on the scores in the aspects of clarity and efficiency as the highlights in the figure below reveal. While most of the students believed that the AR app enhanced their learning in the course, some complained of difficulty in perusing the app. A few students said that instructions in the app were not adequate in some cases, and they required more time to figure out how to work some options. This implies that while there is much promise in the utilization of AR in facilitating students' learning; the aspect of interface design and user instructions should be given much emphasis as a way of ensuring that all the students can easily work with it.

The same was seen with the accuracy aspect which depiction was not clear and showed mixed performance. Some respondents said that, in terms of precision and in giving information and assisting in completing programming tasks, the AR app was accurate and highly useful for them, on the other hand, some respondents 'felt that some aspects of the program still require enhancements to meet and/or fulfill the requirements of the learning process'. This explains the probable exhaustion used by the students through the feedback collected in the survey that would call for advancement of the developmental cycle of the AR app to improve the application and make it fit the expectation of the students. In resource-sharing perspective, present study revealed that implementation of AR apps leads to increased interaction between the students. In this respect, the application and integration of AR is effective in individual learning, as well as encourages students to collaborate as they explain to each other what was passed during the knowledge-sharing session. This has an implication that with the help of AR, teaching and learning context may be characterized by higher degree of interaction. In conclusion, this present discussion makes it apparent that the experience of the user plays an important role in the integration of AR technology in education. The results presented in this paper also reveal the fact that the application of AR may enhance considerably the attractiveness and the stimulation of learning, at the same time, the research points out the necessity of designing user-friendly applications and providing clear instructions. This evaluation provides valuable insights for APP application developers and educators, showing that with the right improvements, AR can be a highly effective tool in enhancing students' learning experience and academic outcomes.

This is applying the constructivist theoretical framework and the cognitive theory of load in understanding how AR can enhance student learning and interest. Within the processes of constructivism, AR enables the construction of knowledge by students through active engagements in experiences with aspects of programming that are usually hard to describe. With AR visualization and simulation students can code and understand the implications of each command as well. Cognitive load theory also offers a basis to this finding whereby AR minimize the cognitive load by presenting information from a more simplified perspective in that it offers visual representation of complex information. This is very helpful, especially for those basic concepts of programming that are usually a bit confusing to the introductive students. AR offers several specific features that support student understanding and engagement, most notably through dynamic visualizations, live feedback, and interactive simulations. Visualizations of programming concepts, such as looping or branching logic workflows, allow students to see how each section of code works in real time. Live feedback features help students identify and correct their errors immediately, reducing the rate of errors that occur. This live feedback also creates a more interactive learning experience and provides direct understanding that is rare in traditional teaching methods.

For educators, the results of this study suggest that the use of AR can guide the development of more effective learning strategies in programming classes. Educators should consider restructuring traditional methods to integrate AR technology as part of a more interactive learning process. For example, educators can combine textbook-based learning sessions with AR simulations that allow students to test concepts learned in real-world scenarios. In this way, AR becomes not just an addition to traditional methods but an integral part of learning that supports deep understanding. The statement that AR "deepens the level of interaction with the material" refers to improved problem-solving skills, critical thinking, and better retention of information. In this study, AR helped students dive deeper into the context of programming problems through hands-on practice that dynamically gave them the opportunity to explore solutions independently. By strengthening problem-solving skills and critical thinking abilities, AR enabled students to internalize programming concepts in a more effective way. The visualizations presented through AR also improved information retention, making it easier for students to remember and apply the concepts they had learned.

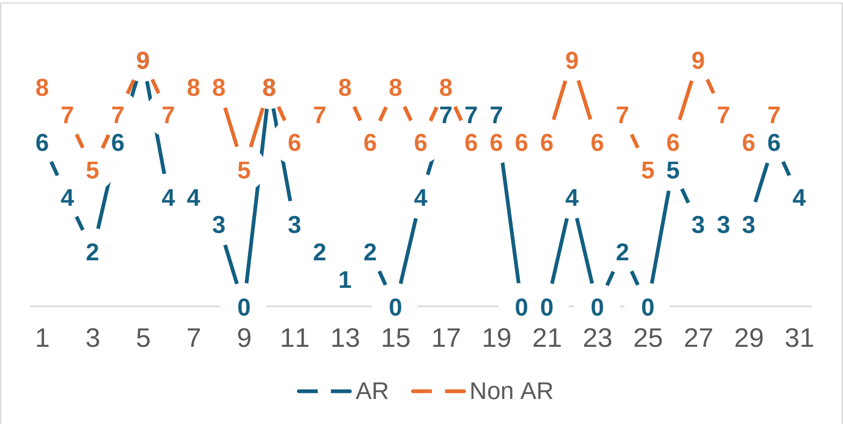
According to the study done by Alkhabra et al. (2023) the teaching and learning that was facilitated through augmented reality it was found that augmented reality has the potential of enhancing the learning interest of the students. However, this study also identified that quite a few AR applications at the same time offered with difficult and relatively not very intuitive UIs, which would decrease the potentiality of their use. Comparatively, the authors of this study established that while the overall attractiveness and stimulation of the apps involved were high, students with certain challenges in learning the apps layouts and using the apps as instructed existed. Consequently, this might imply that although there is significant development in AR interface design, the interfaces could be more effective and comprehendible to users.

Arici et al. (2019) also established that through their study on AR in engineering training that even as AR increases the chances of learners' participation and learning outcomes some of the users were frustrated because the application was not well explained. Some students in this study also mentioned that they are still unclear about the navigation and instruction of the AR applications and thus indicated that, although there has been enhancement in the attractive and stimulating factors aspect, there is still the problem of clarity and effective guidance to solve. Furthermore, Mubai et al. (2020) in a study that compared the effectiveness of the use of AR in health education realized that the use of AR offers an innovative and engaging manner of learning; however, the implementation of the technology is partially limited by high costs and unsuitable hardware. Thus, the applications used in this study can be installed from more ordinary and cheaper devices like smartphone and tablets what indicate the progress in accessibility of AR technology. This makes it possible for more learning institutions to incorporate and use AR without having to make significant investment in the technology.

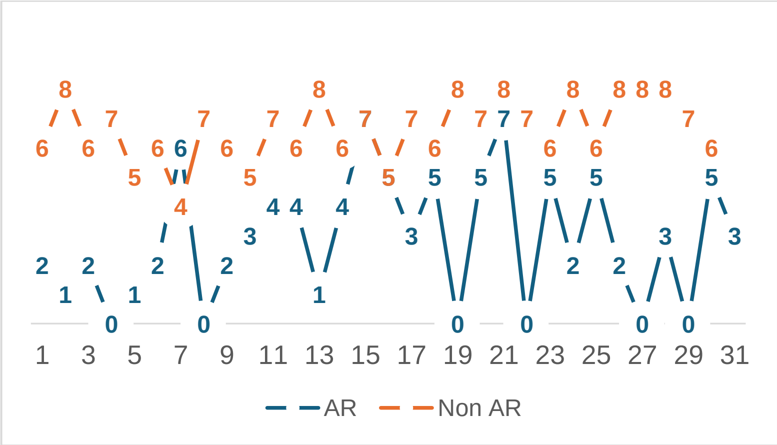
Moreover, this investigation includes a new angle in addition to the existing studies by exploring AR impact on collaboration learning which is scarcely investigated. The study uncovered that AR not only aids in individual learning, but also facilitates discussions and interactions between students enhancing collaborative learning for the same. In summary, the comparison with relevant studies illustrates that this research managed to address some of these progressions concerning AR use in education especially regarding its enhancement and motivation, as well as availability. Yet, it seems there are still confusion and inefficiencies in implementation as noted through their findings highlighting the necessity of reevaluation and improvement. Collectively, this research adds to a growing body of work in investigating how AR might be leveraged for improved learning effectiveness and engagement within games but also provides new ways forward for developers and educators responding the existing obstacles.

Log Activities, Display Records and Error Rates

The analysis of activity logs and screen recordings in this study focuses on how data on students' interaction with AR are used to understand their learning process in depth. This analysis aims at identifying usage patterns, difficulties encountered, and error rates during coding completion.



(a)



(b)

Fig. 2. Syntax Error Rates (a) and Logic Error Rates (b) of Control and Treated Groups

Among all the students, the student who made the most errors was Student ID 010 who made 8 syntax errors and 3 logic errors hence making the total of 11 errors. This also points a big problem in comprehending syntax rules relating to programming languages. On the other hand, Students 009 and 015 had a low total error count and recorded 2 and 0 errors respectively that is why the two understood the concepts of programming syntax and logic well. Syntax errors were found to occur more frequently than the logic errors pointing towards the fact that students seemed to face more difficulty in writing down proper syntactical correct code than in having proper logic for the whole design. While some students made relatively small number of syntax and alike errors, such as ID 001, 002, 003, and 019, others with ID 005 and 007 made almost the same number of syntax and logical errors which should point to a different, potentially more profound type of the problem with understanding the programming material.

Again, students who made many errors as to the assessment, for instance students ID 010 and 030, took more time to complete the task, for instance, 56 and 45 minutes respectively. This implies that there could be a negative relationship with the number of errors and the time taken to accomplish a task due observe that more errors can slow the rate of task accomplishment possibly due to debugging. However, the students like ID 025 and 024 those having less numbers of mistake took less time (54 minutes and 36 minutes) to solve the problem. The following allows having a better understanding of the impact of Augmented Reality (AR) in learning programming. Students who make fewer mistakes and those who take less time to complete the material may be more benefitted with the use of AR, like in ID 022 & 021. Nonetheless, the students having more errors may need some individual learning approach and hence use the AR technology more appropriately.

Table 7 - Linear Regression of AR Log Activities and Display Record

	B	t	Sig.
Constant	15.886		
Login	0.894	8.552	0.000
Action	0.823	7.731	0.002
Coding Attempts	0.854	8.756	0.000
Sample		61	
P-Value		0.000	
F Value		17.773	
Regression Equation		$y = 15.886 + 0.894x1 + 0.823x2 + 0.854x3 + \varepsilon$	

In accordance with the results of the activity log analysis, the students engaged with the features of the AR application including code visualization, simulation of the result of a program, and other interactive tutorials. The log data captured each activity performed by a student, time spent on each module, number of tries within that module before the student was able to complete a particular activity correctly, and the kind of mistake(s) a student was most likely to make most of the times. The studies show that students, who apply AR, systematically interact with more options and spend more time in studying the material comparing to regular learning process. This may mean that AR provides the ability to draw out the curiosity and desire to explore the content of the students. Recordings of the screens demonstrate the activities of learners concerning augmented reality apps. The researchers were able to pinpoint specific instances wherein the students' encountered issues or had some misunderstandings and see how they worked out the problem. For instance, videos on the screen captured cases where students had challenges in comprehending written text and rather preferred visualization and animation while learning programming. Furthermore, the provided video also depicted that student used the simulation option to refine their code and this evidence also supports the hypothesis that AR makes understanding of the debugging process less complicated.

Similarly, analyzing activity logs and screen recordings the authors identified the most frequent mistakes made by students including the syntax and logic mistakes. The data very beneficial particularly in having an insight on where the students still require much practice and or even refining of instructional resources. This analysis also disclosed that students who used the help and the tutorial elements of the AR application more frequently were making fewer mistakes, and the overall concept mastery improved. In the discussion of these findings, the argue is made that AR is not only an effective mode of teaching and learning but also an effective mode of assessment. It is possible to measure the patterns of interaction and the problems occurring in a class, and consequently, prepare the necessary educational interventions for students. Further, the information gathered here can be utilized by the developers of the AR app in a way that enhances the characteristics of the app so that its application becomes even more purposeful, and helpful in terms of learning. In sum, this paper has illustrated that the use of activity logs and screen recordings can offer a level of understanding of the students' learning process and the efficiency of the AR apps in teaching programming. It should be noted that these discoveries not only prove the effectiveness of AR in enhancing students' interest and knowledge, but also demonstrate the places that need more enhancement to capture the full potential of the given technology in teaching process.

Huda et al. (2021) in their study on the application of AR in engineering course found out that AR has a significant potential in enhancing the spatial visualization of the students, however, there is limited literature on how students engage with bas applications. They adopted direct observation methods of data collection, which, as found from the current study, was found to be less effective in identifying the specifics about user interaction as applied in activity logs and screen shots. According to the findings of this study, digital methods provide a better way of capturing usage patterns about AR and the challenges faced by the learners leading to better understanding of how AR can be optimized in learning environments. The paper of Vicente dos Anjos et al. (2021) which focused on the use of AR in teaching history showed that AR can have positive effects to students' engagement; however, it did not discuss the findings of the quality of errors students made or how they accomplished the tasks. In this case, activity logs and screen recordings offered detailed information of the nature of programming errors committed by the students and how they were solved. For instance, the study discovered that learner used syntactical errors that the simulation as well as debugging components in the AR app rectified. These findings extend the prior knowledge about the nature of AR application to enhance a more detailed and discrete learning process within the program experiments context.

Study of the integration of AR in different fields of education did not even investigate the logs of users' activity. Some of the insights they discovered were that AR can enhance learning motivation, but they never looked at how the interaction user has with AR applications influences learning. Conversely, the intensity of the communication of the participants with AR features in the current study was associated with less errors and better understanding of concepts. An analysis of the activity log provided evidence that the more the students engaged with the help and tutorial features of the AR app the better the learning outcomes Jerry & Aaron (2010). This goes to support the need to conduct activity interaction analysis to reveal the effects of AR on learning. In their study on employing augmented reality in learning of physics, employed surveys and interviews to gather user experience feedback. They discovered that students had increased motivation and interest, but the researchers had no quantitative information about the students' use of the AR application. This current study which adopted activity logs and screen recordings offered evidential proof that students, while programming, engaged more time and effort when applying AR and had better exploration patterns. This seems to imply not only the fact that AR enhances the amount of engagement but also deepens the level of interaction with the materials Faridi et al. (2021).

In turn, the comparison between the results of this work and the previous publications indicates that this research fills the gap in the analysis of user interaction with AR applications based on activity logs and screen recordings. The evidence contributes not only to the proposition that AR may enhance students' interest and comprehension but also to the proposition that finely grained interaction analysis may reveal precise areas of difficulty. This study extends prior knowledge about AR to enhance LU according to specific data to give concrete suggestions to app developers and educators. The implementation of AR in programming curricula can assist educational organizations in offering a more encouraging and engaging learning environment for learners who have a hard time grappling with logical presentation of program flow. By using AR, educators can focus on specific learning difficulties inherent in programming such as visualizing the logical structures or program flows. To the best of our knowledge, this study enriches the existing technology education literature by presenting the positive impact of AR in programming education. The use of AR for assisting to explain programming concepts means the new prospects for the development of more effective and interesting learning approaches. Therefore, the research's innovation is twofold: through the integration of a multimodal approach in AR and the engagement in developing interactive learning by applying the ASSURE framework in the context of basic programming. The results of this study add significantly to theory on interactive learning, providing support for the role of visual-based technology and real-time feedback to overcome the constraints of traditional approaches to learning.

5. Conclusion

This research has aimed at understanding the feasibility of augmenting the learning of basic programming courses with the help of Augmented Reality technologies as well as understanding the possibilities of multimodal approach in the contemporary classroom. As the findings suggest, the introduction of AR in the teaching-learning process positively affects the response of students; enhances understanding of programming concepts and increases motivation among learners. AR was found greatly helpful in illustrating sometimes rather abstract concepts that cannot be easily explained with a word of mouth only. It also leads to increased interaction because the student can directly interface with this module through simulations and graphical models presented in (real time). It helps in governing the students and at the same time helps in giving collaboration to students also. this led to further appreciated that learning experience basic programming with incorporation of Augmented reality can enhance students learning and increase their comprehending knowledge. The use of AR not only engages the students, but the way classroom teaching will become more exciting and less monotonous, might make such institutions use such a form of technology as AR in their course curriculum. Hence, this study expands on the interactive learning theory as well as constructivism to show how learning with AR enables the success of such concepts. Through the graphical notation, and real-time feedback, AR can minimize the cognitive load hence enabling students to think critically and solve problems. By applying cognitive load theory, the findings of this study back the identification of the fact that understanding can be increased through minimizing the cognitive load when engaging with more concrete and less complicated content being studied by the students. From a practical point of view, this work offers a look at how AR technology may be implemented as best practices to support teaching in programming classes. When programming instruction combines AR, it becomes possible to turn the teaching-learning process into a more creative, knowledge-intensive, and experimental process. This work establishes that features like succinct answers that are obtained instantly, and virtual environments of interaction assist in minimizing programming mistakes and expediting learning, particularly in subjects offered to learners with minimal experience.

The implication of these findings is especially useful to the education of programming where, AR can act as an innovative solution to the difficulties warranted when teaching abstract knowledge. However, there is some weakness of the study in the following areas that include. The study sample might not represent the general student population. Nonetheless, this study does not involve the assessment of multiple learning environments, and the findings, therefore, cannot be generalized to other classes. The observation period also has constraints in that it may not be sufficient to capture how the use of AR in leaning will impact in future. For the future research it is suggested to include a greater number of participants and make the study more diverse, also to use AR in different subjects to determine its efficiency in different spheres. In addition, long-term research is needed to evaluate the sustainable impact of using AR on learning outcomes and students' motivation. The development of more sophisticated AR technology integrated with automated evaluation tools can also be a focus to improve its effectiveness in learning.

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