

CompARch: Integrated Augmented Reality Computer Architecture Learning App

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Abstract

This report discusses the development of an application with integrated Augmented Reality (AR) that is designed to help students learn about computer architecture. Many students find it hard to understand complex concepts using traditional teaching methods, which often rely on textbooks and flat diagrams. The AR application aims to provide interactive 3D models of computer components, making learning more engaging. The project followed a structured approach called the ADDIE model, which includes analysis, design, development, implementation, and evaluation. Initial testing showed that students who used the AR application reported better understanding and increased interest in the subject. The report concludes that AR technology can improve learning in the computer architecture subject and suggests further work to enhance the application and expand its content.

1. Introduction

Learning computer architecture can feel like trying to understand a complex machine by only looking at a flat, black-and-white diagram in a textbook. Furthermore, concepts like pipelining, memory hierarchies, or how Central Processing Units (CPU) and Graphical Processing Units (GPU) work remain abstract and hard to visualize for many students [1]. Traditional teaching methods, for example, such as textbooks, slides, and 2D images, often fail to make these ideas tangible and palpable, leaving students struggling to connect theory with real-world systems [2].

Computer architecture is a core subject for students pursuing Information Technology (IT) and Computer Science. However, traditional teaching methods, such as textbooks and two-dimensional (2D) diagrams, often fail to help students visualize complex hardware components like CPUs, GPUs, and memory systems [1]. These methods lack interactivity, making it difficult for learners to understand abstract concepts such as pipelining, cache hierarchies, and data flow [2].

Augmented Reality (AR) technology offers a promising solution by enabling students to interact with three-dimensional (3D) models of computer components in real-time. Research shows that AR improves engagement and knowledge retention in Science, Technology, Engineering, and Mathematics (STEM) education by up to 40%

compared to conventional methods [3]. This project leverages AR to create an immersive learning tool for computer architecture students or anyone that interested to learn about the subject.

Despite the importance of computer architecture, students struggle with the subject for these three main reasons. Firstly, limited visualization tools: static. This is because diagrams in textbooks cannot demonstrate dynamic processes like data movement between the CPU and memory [4]. Furthermore, having low engagement, which is passive learning methods as PowerPoint slides or lectures, reduces motivation and comprehension [5]. Thirdly, lack of hands-on experience: Without physical hardware access, students resort to memorization instead of practical understanding [6]. Therefore, to address these issues, this project developed an AR application that allows students to explore 3D models of computer components interactively.

The project objectives are:

1. To identify key knowledge requirements for learning computer architecture.
2. To develop an AR application with interactive 3D models of computer components.
3. To evaluate the usability and effectiveness of the application.

The application is developed to help a student understand in various ways of understanding. For example, learning, quiz, and AR sections that give better feedback and knowledge to the student by using their features. This help user or student to increase their knowledge by memorizing the simple slides, a well-designed quiz section, and better visualization of core computer components [3]. The final product will be a working AR application that displays 3D models of computer components with interactive features. It is expected to be easy to use, informative, and suitable for mobile devices. Thus, students will be given a survey after using the app, and their feedback will be used to evaluate the app's usability and learning effectiveness.

Traditional teaching methods for computer architecture face several well-documented limitations. Static two-dimensional representations in textbooks fail to convey the three-dimensional nature of hardware components and their dynamic interactions. Approximately 70% of students struggle with visualizing critical concepts such as cache hierarchies and instruction pipelining when relying solely on conventional learning materials [4].

AR has emerged as a powerful educational tool across various STEM disciplines. Iatsyshyn and her group demonstrate that AR applications improve spatial understanding and knowledge retention by allowing learners to interact with virtual models in real-world environments [7]. In engineering education specifically, AR implementations have shown measurable improvements in student performance, with some studies reporting up to 40% better comprehension compared to traditional methods [1].

While AR applications exist for various technical subjects, few specifically address computer architecture education. Rahman and his group note this gap in their analysis of educational technology, highlighting the need for specialized tools that target the unique challenges of computer hardware education [2]. The current project seeks to address this need by developing an application tailored to computer architecture concepts with appropriate pedagogical features.

Table 1 Strengths and Weaknesses of AR in education field existing research articles

Research Title	Strengths	Weaknesses
Personalization of learning using adaptive technologies and augmented reality [5]	<ul style="list-style-type: none"> - Comprehensive review of adaptive technologies and AR in education, providing a holistic view of current trends. - Detailed analysis of adaptive systems, including content, evaluation, and sequence adaptability. - Emphasis on hybrid cloud solutions as a promising direction for integrating adaptive learning and AR. - Practical recommendations for educators on implementing adaptive cloud-based systems and AR tools. 	<ul style="list-style-type: none"> - Limited empirical data or case studies to validate the effectiveness of the proposed recommendations. - Lack of quantitative metrics (e.g., accuracy, performance benchmarks) to measure the success of adaptive systems or AR implementations. - Potential scalability challenges for hybrid cloud solutions, especially in low-resource settings.

Table 1 (cont.)

Research Title	Strengths	Weaknesses
A Review of Augmented Reality Apps for an AR-Based STEM Education Framework [4]	<ul style="list-style-type: none"> - Proposes a clear framework for integrating AR into STEM curricula, useful for policymakers and educators. - Identifies tangible benefits of AR, such as improved student engagement, motivation, and understanding of complex concepts. - Addresses challenges in STEM education (e.g., lack of lab equipment) and how AR can mitigate them. 	<ul style="list-style-type: none"> - Limited discussion of technical limitations (e.g., hardware requirements, software compatibility). - No quantitative comparison of AR tools' effectiveness across different STEM disciplines. - The framework lacks empirical validation or pilot testing in real-world educational settings. - Overlooks potential downsides of AR, such as cognitive overload or distraction in classrooms.
Application of augmented reality technologies for preparation of specialists of new technological era [7]	<ul style="list-style-type: none"> - Highlights real-world examples (e.g., Chernobyl NPP ARCH AR, NASA's HoloLens use) to demonstrate AR's practical utility. - Identifies key barriers to AR adoption (financial, professional, methodological) and suggests policy-level solutions. - Emphasizes the role of AR in enhancing student motivation and professional competency development. 	<ul style="list-style-type: none"> - Lacks a structured framework or unified theory for AR implementation in specialist training. - Limited critical analysis of AR's drawbacks (e.g., cost, accessibility, ethical concerns). - Few concrete recommendations for overcoming financial and technical challenges in low-resource settings.

The **Table 1** reviewed studies collectively emphasize the growing potential of AR in enhancing educational experiences across different domains. The first article highlights the integration of adaptive learning systems with AR, offering a comprehensive analysis of adaptability in content delivery and proposing cloud-based solutions [5]. However, it lacks empirical validation and measurable performance metrics. The second article focuses on AR applications in STEM education, providing a structured framework and identifying practical benefits such as improved engagement and understanding [4]. Yet, it overlooks technical limitations and does not support the framework with real-world testing. The third study presents real-life use cases of AR in professional training, showing its motivational and practical value, but lacks a structured implementation model and a critical analysis of drawbacks [7]. Across all three studies, while the theoretical and conceptual contributions are significant, there is a common gap in empirical testing, scalability considerations, and detailed technical evaluation. These findings suggest that future research should focus on real-world implementation, quantitative assessment, and strategies for adopting AR in low-resource educational settings.

Table 2 Comparison of CompARch with existing project features

Features	CompARch	Development of Augmented Reality Based Learning Media to Introduce Computer Components to students in Senior High School [8]	Development of Augmented Reality Application for Learning Computer Network Device [9]
Lecture notes/ learning slides	Yes	No	No
AR Integration to show a 3D model	Yes	Yes	Yes
Quiz Section	Yes	No	No

Table 2 shows the comparisons of the availability of features in these three educational projects, CompARch application with two developed projects for computer components and computer network devices [8][9]. The comparisons are based on three key features in education, which are lecture notes or learning slides, AR integration to show a 3D model, and a quiz section. The CompARch application shows that it provides three features which are having a learning slides section, an AR button option to use the AR function to show the 3D model of components, and a quiz section to test the users' or students' understanding and knowledge about the computer architecture subject. Therefore, this is to ensure the best experience for students or users in the learning environment.

The most important features to highlight here are the lecture slides and quizzes. For example, it is more convenient if an application can gather all the notes in one place, which is implemented in the CompARch application. Moreover, students can access the learning slides from the application easily, and anywhere, as everyone has a mobile phone in their pocket [3]. In addition, the provided learning slides provide up-to-date information and a clear display, which means no blurred or unrecognizable characters. Furthermore, the quiz section is a must to make sure students understand what they were learning in the app, and they can test how far their knowledge of the computer architecture subject [1].

2. Methodology

Fig. 1 shows the ADDIE methodology stages. In this project, the methodology implemented is the ADDIE linear model, which stands for Analysis, Design, Development, Implementation, Evaluation [10]. The ADDIE model is a structured method used to develop effective learning programs. It consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. This model helps ensure that the training is planned properly, meets the learners' needs, and achieves its objectives.

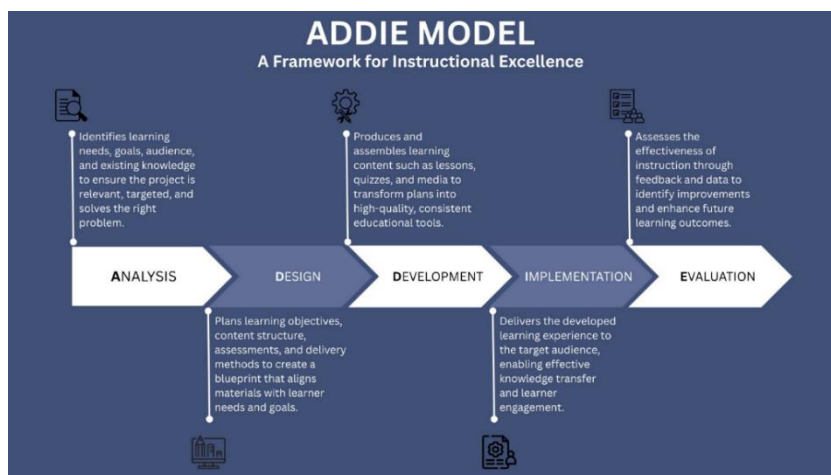


Fig. 1 ADDIE methodology framework structure

In the analysis phase, the phase identifies who the learners are, what they need to learn, and any potential challenges. In the design phase, the phase plans the content, delivery method, and how learning will be assessed. Then, in the development phase is where the creation the learning materials such as slides, videos, or modules. Next, in the implementation phase, the training is delivered to learners through suitable formats like online or face-to-face sessions. Finally, the evaluation phase measures how effective the training is by collecting feedback and analysing results.

In conclusion, ADDIE provides a clear process for building well-organized and goal-oriented training programs, making it a popular choice in education and professional development as well as in mobile application development [10].

2.1 ADDIE Phases

In analysis phases, focus on who the target user will be and who will use the application. A survey was conducted using the questionnaire method, which utilized a Google Form platform to gather requirements. A survey was distributed to 32 respondents, primarily students in year 2 and some in year 3, who lack the learning computer skills Architecture course. The responses give a good idea and some key information on application development in computer architecture courses.

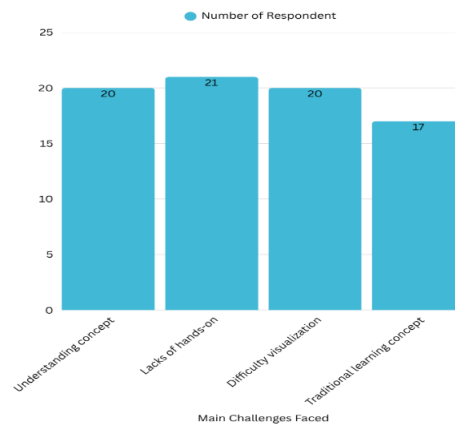


Fig. 2 Analysis result of the main challenges that computer architecture students faced

The project began with the analysis phase, and has conducted a questionnaire through Google Forms about requirements to meet their expectation. **Fig. 2** shows one of the questionnaires, which is the statistics of the main challenges in learning computer architecture that were gained from the results. A total of respondents took the questionnaire were 32 respondents. There are four main challenges stated: understanding abstract concepts, lack of hands-on learning, difficulties with how computer components work together, and boring traditional learning concepts.

Furthermore, the most chosen option, which 21 out of 32 students chose, is the difficulties with how the computer components work together. This is because when students learning with only theories and lecture slides, they do not have the experience nor much enough knowledge, as they just know the fact of the components, not how the components work in a computer architecture [4]. Other than that, the second and third options tied with 20 students choosing, about understanding abstract concepts in computer architecture and lacks hands-on in the subject. It shows that students need an actual presentation that they can interact with computer components, and at the same time, get to understand the concepts in computer architecture [2]. Lastly, the least chosen option is traditional learning concepts that are less engaging, with 17 respondents. Thus, the project focused on making engaging environment with an interactive AR 3D model, accessible learning slides, and quiz section that helps student to improve their knowledge in computer architecture.

The design phase focuses on brainstorming the details of the study materials, quizzes, and AR features, as well as event flows and storyboards, to identify interesting ideas for inclusion in the application. The purpose of this phase is to enable students to use the application effectively and comfortably. The application interface, including the button graphics and layouts, is designed using Figma.com. This phase aims to enhance the application's appeal and engagement for users, particularly students. Regarding the lecturer's slides, the design was adapted from PowerPoint to a more readable and concise Portable Document Format (PDF) format using Canva. The goal was to make the slides more understandable and accessible for users to read and take important notes. This phase examines the kinds of skills required to achieve the objectives established for the target audience, specifically students who are taking Computer Architecture subjects. To accomplish this application, the Android platform is selected as the main platform for this project due to its user-friendly system, ease of implementation, and various advantages for this application. The application will use buttons to interact with and navigate the user interface throughout the different scenes. Our theme application is blue and white.

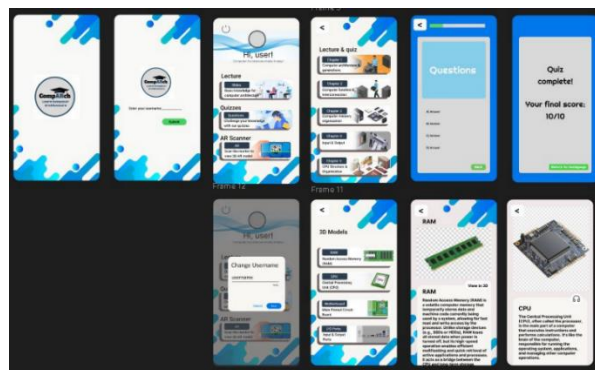


Fig. 3 Overall Application Interfaces and Flow

Fig. 3 shows the application screens and interfaces flow when using the application. The application will display an introduction page that has the CompARch application logo. Users must tap the screen to move to the next screen, which is about the name input (username), and click the submit button to generate the username. Next, the user will face the homepage of the application, which has three big buttons such as lecture, quizzes, and AR scanner section. At the top, there will be a profile photo and username under it, user are able to edit their username as they wish. The user must follow the instructions where user are limited to enter 15 characters and below for validation. The validation helps users to avoid inserting any unwanted characters in the username, such as symbols and numbers. Next, the homepage that shows 3 buttons as 3 main functionalities of the application. First, if the user chooses the lecture section, there will be displayed other screen with 5 more buttons for chapter slide learning, such as chapters 1,2,3,4, and 5. Therefore, the user can answer the quiz either after reading the learning section or not. The features are the same for the quiz section, which has 5 buttons for each chapter. At last, the user is able to retake and view the answer after answering the quiz. It's better to improve user understanding with the correct answer provided by the application. Lastly, the AR scanner section allows the user to choose any computer component that the user wants to see. The view concept is based on 3D pictures, thus the user is able to rotate, zoom and view the description about the component. The component includes such as Random Access Memory (RAM), CPU, Random Access Memory (ROM), etc. Thus, helps to strengthen the user's understanding of the computer component by using these features.

After the data needed is obtained and the design has been made, the process can proceed to the development phase. The development phase is a phase where developers start to build the backend of the system or application using several tools and an Integrated Development Environment (IDE). For this project, we decided to build the code and functions of the application using the Flutter tool and Visual Studio Code (VS Code) as our IDE. These tools are essential for our application's development. In this implementation phase, we focus on deploying the developed learning modules, which include accessible learning slides, quizzes, and AR 3D models, to the target audience as for this context are the students who are studying computer architecture. This phase ensures that the app is functional and effectively supports interactive learning, as it is one of our main objectives in making this project. For the deployment strategy of the CompARch application. the app is deployed on mobile devices specifically targeting the Android platform, as most students are equipped with smartphones for accessible, on-the-go learning. A pilot test will be conducted with target audiences for 4-5 days to collect feedback regarding our app's usability, engagement, and learning effectiveness. We have also considered providing support for the students using our app by providing a help section and space in feedback forms so that we can fix the issues.

During the implementation phase, we faced some challenges, for example, as some of our buttons were not working, like the exit button. we ran a debugging process and ensured it worked properly. Moreover, we faced some problems when integrating AR, especially the Quick Response (QR) code that is supposed to show the computer components with correct measurements, but it did not. To solve that, we compressed it and made it a smaller file size so it would not glitch out and output smoothly. For the evaluation phase, we used a survey method for the evaluation process, which provided a questionnaire using a Google Form platform. It is to ensure that the feedback is on the user's experience in using the application. The focused sections are accessing learning section (slide materials for the computer architecture subject), the quiz environment and experience, and the AR integration section, where the user can interact with it well or not.

3. Results and Findings

3.1 Evaluation of User Feedback on App's Effectiveness

The result survey evaluation after giving the application product to the tester, mainly the students in computer architecture and students keen to test it, shows which features are successful when running the application.

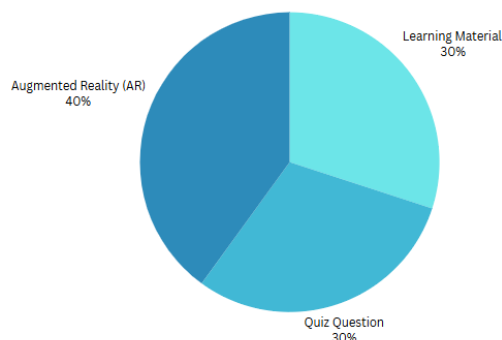


Fig. 4 Overview of pie chart represent successful main functionalities in the app by users

The **Fig. 4** above shows the overall percentage of how satisfied user able to interact with the features such as AR, learning section and quiz section. AR shown the 40% percentage because of the feature similar like gamification where user able to rotate, zoom, and view description about the component. It helps to improve the understanding about the computer components better such as in term of the real-world visualization by using the feature. Learning Material that shown 30% percentage of average user that use the feature. Users able to view the slide material that created by one of UTHM lecturer, it's still related but have a bit adjustment which shorter from the original slides that have been created. Thus, users have the shortest timing to understand the slide safely. Lastly, the quiz feature that help user to apply their understanding by answer a set of question by a chapter. Certain questions were provided pictures as their reference and hint to answer the question. Thus, it helped to improve the user visualization that they able to find the answer only by a picture given.

3.2 Usability Testing

To identify the usability of CompARch application, we conducted a structured usability testing with 10 diploma students from Universiti Tun Hussein Onn Malaysia (UTHM). The participants selected were varied from students who had learned computer architecture subject (5 students) and students who had not taken the computer architecture subject (5 students). This is to ensure the balanced evaluation of CompARch's accessibility. The testing procedure includes a direct observation followed by a detailed questionnaire to the test users, allowing us to gather both behavioral and subjective feedback.

During the observation phase, the test users were asked to complete three main tasks: accessing lecture notes, taking a quiz and viewing the 3D AR model of core computer components. These tasks were chosen purposely for evaluation of CompARch's primary functionalities under realistic conditions where the test users have minimal knowledge about the CompARch application. The test users were given minimal guidance to simulate a first-time experience, and all their interactions were observed to evaluate the difficulties and errors faced during the testing. Metrics such as task completion time, success rate and instances of user's hesitation were recorded during the testing. After the user has completed the testing phase, participants were asked to fill out a questionnaire on Google Form designed to measure their satisfaction of CompARch's usability and ease of use during the testing. The survey took on a structured 5-point likert scale (1 = Strongly Disagree to 5 = Strongly Agree) for quantitative assessment of user's experience, followed by a multiple-choice question to identify specific areas for improvement.

3.3 Key Findings

The observation results provided that all participants successfully navigated and viewed the lecture notes with an average completion time of 1.2 minutes. The quizzes were also completed with an average time of 3.5 minutes. No major problems were faced, though some users with less knowledge about computer architecture subject took longer time due to reviewing the slides before answering.

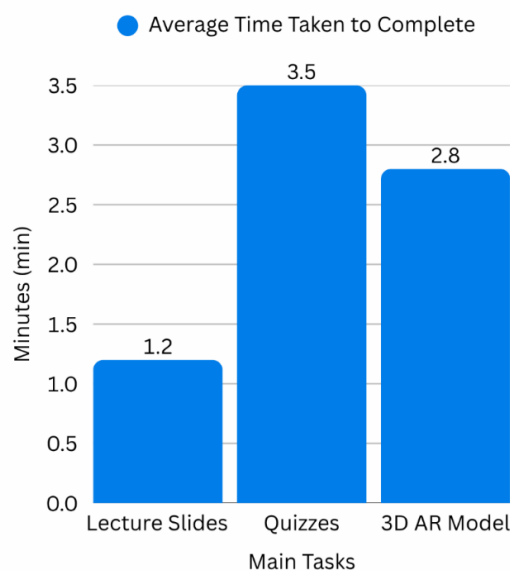


Fig. 5 Overview of bar chart represents average main tasks completion time taken by users

Although, the AR 3D model section average completion time is moderate, it has proved to be more challenging as 40% of users could navigate to the 3D model and manipulate it intuitively while 60% struggled to locate the AR feature initially. Performance testing highlighted that AR models experienced slight delays on low-end Android devices, though high-end devices loaded the 3D models smoothly without any delay.

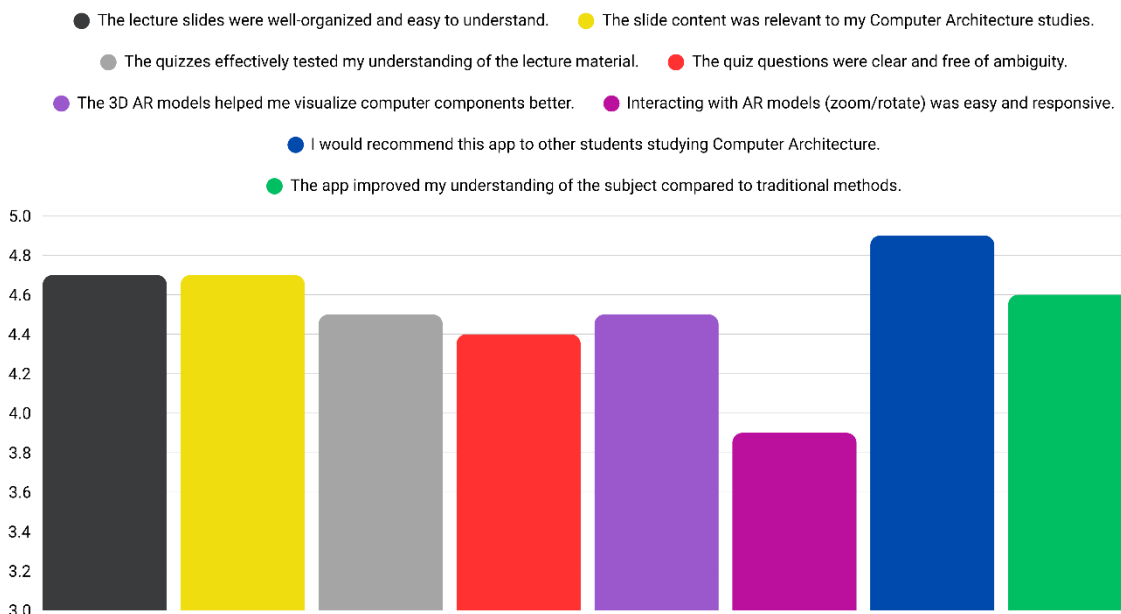


Fig. 6 Overview of bar chart represents average ratings for each CompARCh main functionality

The bar chart results show strong performance across all features, with lecture slides receiving the highest score (4.7/5), indicating users found them highly accessible and useful for learning. Both quizzes (4.5/5) and the 3D AR model (4.5/5) scored slightly lower but still demonstrated consistently positive feedback.

The minor gap between lecture slides (4.7/5) and the other features (Quizzes and 3D AR models) (4.5/5) could reflect that slides are more straightforward to use, whereas quizzes and AR require additional user effort (e.g., answering questions or manipulating 3D models). Notably, no feature scored below 4.5, confirming the app’s core functionalities meet user expectations effectively. However, some users noted that the AR features (rotate and zoom) placement in the app was not easy to find at first. Several suggested adding a short tutorial to guide new users on how to utilize the 3D AR features.

4. Conclusion

In conclusion, this project, CompARCh application, aims to be an interactive, easy-to-use, and accessible education application that focuses on computer architecture by integrating AR technology. In addition, the AR makes the learning of computer components more understandable by allowing users to look and explore the computer component model itself in virtual space, which uses AR medium to execute it. This way, users can increase their knowledge and practice it on quizzes provided in the application’s quiz section.

Nevertheless, this project would be better if we add some more modifications and add-ons. For example, in the future, we will implement a database system for much more convenient saving and progress made in the application without loss, even if the application is deleted. For future improvements, we recommend expanding the AR features and incorporating user progress tracking to personalize learning.

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Conflict of Interest

There are no conflicts of interest related to this work

Author Contribution

Muhammad Amri Bin Mohd Arshad and Nik Mohd Nasrul Hakimi Bin Nik Mohd Kamaruzaman managed design and survey analysis. Muhammad Farhan Bin Zulkalam and Harith Hakimi Bin Jamalullail were responsible for

software development and programming. Shelena Soosay Nathan supervised the project and reviewed the final manuscript. All authors contributed to and approved the final document.

References

- [1] J. Garzón, "An overview of twenty-five years of augmented reality in education," MDPI AG, Jul 2021,
- [2] K. R. Rahman, S. K. Shitol, M. S. Islam, K. T. Iftekhar, and P. Saha, "Use of Metaverse Technology in Education Domain," *Journal of Metaverse*, vol. 3, no. 1, pp. 79–86, 2023.
- [3] A. Hajirasouli and S. Banihashemi, "Augmented reality in architecture and construction education: state of the field and opportunities," Springer Science and Business Media Deutschland GmbH, Dec, Jan 2022, .
- [4] C. H. Godoy and J. Philippine Navy, "A Review of Augmented Reality Apps for an AR-Based STEM Education Framework," arXiv preprint arXiv, 2022.
- [5] M. V Marienko and M. P. Shyshkina, "Personalization of learning using adaptive technologies and augmented reality Institute of Information Technologies and Learning Tools of the NAES of Ukraine," 2020.
- [6] T. Alkhasawneh and M. A. S. Khasawneh, "The effect of using augmented reality technology in developing imaginative thinking among students with learning difficulties," *International Journal of Data and Network Science*, vol. 8, no. 3, pp. 1679–1688, Jun. 2024.
- [7] A. V Iatsyshyn, "Application of augmented reality technologies for preparation of specialists of new technological era," *Augmented Reality in Education: Proceedings of the 2nd International Workshop (AREdu 2019)*, Kryvyi Rih, Ukraine, no. 2547, pp. 181-200, 2020.
- [8] S. Hafiz, N. Ginting, B. Singh, and J. Zhang, "Development of Augmented Reality Based Learning Media to Introduce Computer Components to students in Senior High School," *International Journal of Educational Insights and Innovations (IJEDINS)*, vol. 2, no. 1, pp. 8–13, 2025.
- [9] M. L. Hamzah, Ambiyar, F. Rizal, W. Simatupang, D. Irfan, and Refdinal, "Development of Augmented Reality Application for Learning Computer Network Device," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 12, pp. 47–64, 2021.
- [10] R. Samsudin, R. Sulaiman, T. T. Guan, A. M. Yusof, M. Firdaus, and C. Yaacob, "Mobile Application Development Trough ADDIE Model," *International Journal of Academic Research in Progressive Education and Development*, vol. 10, no. 2, pp. 1017–1027, 2021.