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PAPER

# What Does an IMoART Application Look Like? IMoART—An Interactive Mobile Augmented Reality Application for Support Learning Experiences in Computer Hardware

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**ABSTRACT**

This study aimed to develop an interactive mobile application based on augmented reality (IMoART), which could contribute to reshaping the learning paradigm in computer hardware courses. The IMoART application employs a marker-based tracking method. Accessible on smartphones, it integrates into the learning process, is attractive to students, and fosters engagement as users can visualize hardware through 3D objects. The application serves as an alternative and supplementary learning tool to make the educational experience more enjoyable while potentially reducing school expenditures. The results of the development process, which involved using the 4D model (define, design, develop, and disseminate), showed that the IMoART application is effective, with notable feasibility scores of 3.68 for the media aspect and 3.81 for the material aspect, as evaluated by media and subject matter experts. User responses from teachers and students further support the positive outcomes of the IMoART application, achieving a robust practicality score of 84.68%. Noteworthy aspects such as ease of navigation, clarity, aesthetic features, and instructional quality demonstrate high practicality. This study contributes significantly to the literature by presenting an evaluated model that offers an enjoyable and efficient learning experience using 3D objects, videos, images, simulations, and interactive animations in the context of computer hardware learning.

**KEYWORDS**

interactive mobile application based on augmented reality (IMoART), interactive mobile application, augmented reality (AR), educational technology, 3D simulation learning tool

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## 1 INTRODUCTION

In recent years, various fields have increasingly embraced information and communication technology (ICT), which has significantly aided and simplified daily activities [1–3]. ICT has sparked numerous innovations, particularly in education. These innovations include the development of interactive learning environments, the utilization of digital learning objects, and the adoption of applications such as Learning Management Systems (LMS). LMS serve as digital platforms that manage and deliver course materials, facilitate online discussions, and assess student progress [4]. They enable students to access learning materials anytime and anywhere, thereby promoting a more personalized and self-directed learning experience.

Technology can complement and integrate with education [5]. In a complementary context, it can support traditional teaching methods [6–9], such as using multimedia presentations to aid classroom learning [10]. Conversely, institutions can integrate technology by adopting an online learning platform, enabling learners to access all learning materials, assignments, and assessments [11–13].

Virtual reality (VR) and augmented reality (AR) are increasingly important educational technologies. VR can provide immersive learning experiences, allowing students to explore virtual environments and better understand complex concepts [14–15]. Similarly, AR can enhance learning by integrating digital elements into real-world situations, such as displaying additional information from a textbook through a smartphone camera [16], [17].

The use of digital learning objects is essential to these innovations. Digital objects such as interactive videos, simulations, gamification, and animations are employed to present learning materials [18]. For instance, computer simulations permit users to visualize complex scientific concepts that may be difficult to access directly [19], [20]. VR and augmented reality (AR) have significantly reshaped the educational landscape by enriching the learning experience and paving the way for more interactive and engaging teaching methods within the educational environment.

These innovations represent recent advancements in ICT that have positively impacted students' learning experiences and augmented teaching and learning processes [21]. However, the utilization of computer hardware in schools often faces several challenges, including physical hardware limitations in computer labs that can lead to students sharing devices and reducing adequate time for exploring and understanding concepts. To address this challenge, AR presents itself as a promising alternative [22]. AR technology allows students to directly access 3D visualizations of computer hardware through their smart devices, eliminating the need for physical hardware in the laboratory [23], [24]. This provides opportunities for independent and flexible learning [25], [26].

Augmented reality plays a crucial role in computer hardware learning by mitigating the physical constraints of computer labs. It enables students to comprehend computer hardware concepts more effectively, free from the limitations of physical hardware. Moreover, AR offers a more interactive and engaging learning experience, aligning well with the characteristics of Generation Z, who are known for their responsiveness to digital technology and visual experiences [27].

The rapid advancement of mobile technology, particularly among Generation Z, underscores the increasing relevance of AR. Sources [38], [40], [41] indicate that most students today have easy access to their smart devices. AR leverages the sophistication of these devices to create dynamic and easily accessible learning experiences. Consequently, the integration of AR into computer-based learning not only addresses physical constraints but also aligns with the technological developments' integral to the lifestyle of Generation Z [28].

Augmented reality not only enhances student engagement through interactive learning experiences but also improves conceptual understanding and provides a more effective learning environment. Furthermore, AR addresses the challenges of physical access and time constraints by allowing students to access learning materials anytime and anywhere, thus reducing dependency on specific physical facilities. This accessibility is particularly important for improving access to computer hardware learning, especially in environments with limited resources. By integrating AR into computer hardware learning, schools can create more efficient, engaging, and responsive learning experiences tailored to students' needs. This technology reportedly holds great potential for stimulating students' interest in technology and enhancing their understanding of computer hardware fundamentals [29–31].

This study aimed to develop an AR application to enhance the effectiveness of computer hardware learning in school environments. We designed the application using a systematic and measurable 4D model, which encompasses the stages of definition, design, development, and distribution. The research objectives extend beyond technology development; they also include evaluating the feasibility of the application and detailing the responses from educators and students regarding the use of AR as a learning support tool in schools.

In this study, we recruited experts who specialize in their respective fields. The media experts are university lecturers with a background in computer engineering education and experience in developing educational media content. The material experts have a background in computer hardware learning and have contributed to this field for seven years. We administered response questionnaires to teachers and students to gather their perspectives on the use of the interactive mobile application based on augmented reality (IMoART). The research questions (RQs) for this study are formulated as follows:

**RQ1.** How can the stages of definition, design, development, and distribution in the 4D model approach be effectively applied in developing an IMoART application to support learning about computer hardware in schools?
**RQ2.** To what extent is the feasibility of the IMoART application for computer hardware learning measured based on the assessment of media and material experts?
**RQ3.** What is the teacher's response to using the IMoART application in schools as a learning support tool when introducing computer hardware?
**RQ4.** How do students respond to using the IMoART application as a learning tool in schools for computer hardware introduction?

## 2 METHODOLOGY

### 2.1 Research design

The methodology employed in this study utilized a research and development (R&D) approach, using the 4D framework consisting of four essential stages: define, design, develop, and disseminate [8]. The adoption of the 4D model facilitated a systematic and iterative progression throughout the development process, incorporating continuous refinement based on testing and feedback. It was expected that this approach would have a significant impact on the development and practical implementation of the application. Figure 1 presents a visual representation of the procedural phases.

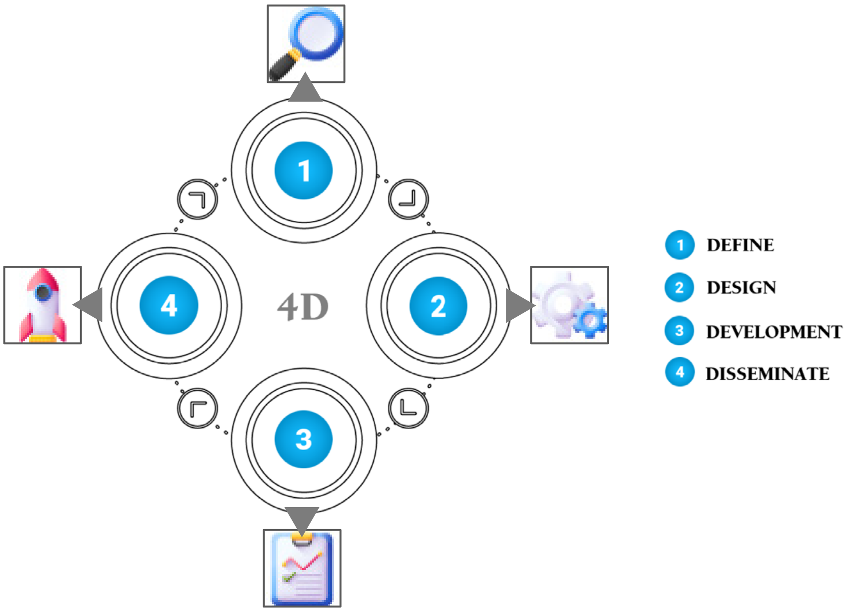


**Fig. 1.** Development procedure using 4D model

**Define.** During the definition phase, two main tasks were performed: the observation process and the examination of the characteristics of the study population. The observation activity was aimed primarily at accurately understanding the current situation. Analyzing demographic characteristics was essential to determining the research sample to be included in the study. These activities are instrumental in providing clear direction and establishing study parameters, enabling the research to remain focused and relevant to our objectives. By conducting thorough observations and analyzing intrinsic population characteristics, a well-informed methodology that aligns with the intended goals and a robust analysis of the data could be conducted.

**Design.** During the design process, we crafted the initial blueprint for the application, carefully considering student needs, teacher competencies, subject characteristics, and available infrastructure support. We then proceeded to gather the necessary materials for application development, including learning resources, supporting media, sound elements, and evaluation questions.

The design phase also involved a thorough examination of student requirements to ensure that the chosen media formats would enhance the learning experience. Equally important was the assessment of teachers' competencies to ensure that the application design effectively complemented their instructional roles. In addition, we considered the available infrastructure support, including factors such as technological capabilities, hardware availability, and other relevant considerations that could impact implementation.

By adhering to the principles of the 4D method, the design stage laid a robust foundation for the development of a pertinent and practical application tailored to the specific learning context.

**Development.** During the development phase, we undertook a series of steps. Firstly, implemented the IMoART application using the previously established framework. Subsequently, we tested the application with a selected cohort of students.

The study aimed to gather data and feedback regarding the effectiveness of the IMoART application in improving students' understanding of computer hardware concepts as presented in the instructional material.

The data and feedback collected were utilized to evaluate the developed IMoART application and identify areas for potential enhancement in subsequent stages. The development phase yielded the finalized IMoART application. It was anticipated that this application would hold the potential to elevate students' educational performance in computer hardware introduction. Therefore, the development phase played a pivotal role in devising effective educational solutions to meet students' requirements.

**Disseminate.** During the dissemination phase, the research findings were communicated to the pertinent stakeholders, including educators, administrators, and professionals in the field of information technology education. The data collection process involved distributing questionnaires to a selected cohort of students to evaluate the practicality of the research findings. Subsequently, the collected data underwent descriptive analysis to glean significant insights.

## 2.2 Population and sample

A sample of 88 students was recruited from the population of 251 students at Harapan Ananda Junior High School in Kubu Raya Regency, Indonesia, employing a random sampling technique. The sample size was determined based on the Slovin formula, a method utilized to calculate the sample size in research, which accounts for large population size to ensure adequate representation. The sample size in this study was deemed sufficient to attain the desired confidence level using the Slovin formula.

## 2.3 Data collection instruments

The validation process comprised two stages involving media and material experts to assess the validity of the IMoART application. Pre-validated and reliable instruments were utilized, including a media expert validation sheet to evaluate the appropriateness of media usage and a material expert validation sheet to assess the content and relevance of the presented material (see Figure 2). Following the validation of the product, user responses to the IMoART application were gathered using a Likert-scale response questionnaire. The questionnaire aimed to gather information on users' perceptions of the practicality of the IMoART application in supporting the comprehension of computer hardware concepts. Prior to utilization, experts validated these instruments, assessing their validity and practicality using the Likert scale [32].

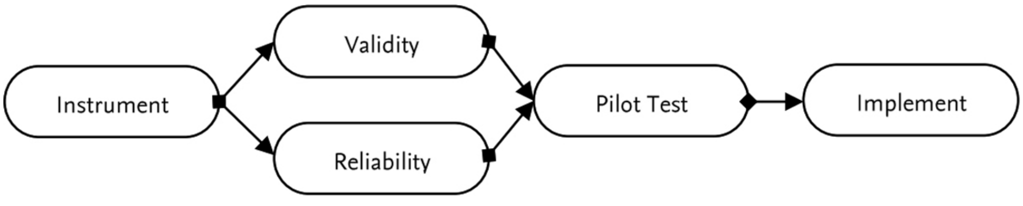


**Fig. 2.** The flow of the instrument development and implementation process

**Table 1.** Validation sheet for the IMoART application (media expert)

| Aspect | Indicator |
|---|---|
| Presentation Technique | **Presentation System:** Clarity, Responsiveness, Speed, Stability. |
| | **Order of Presentation:** Logic, Element Connectivity. |
| Presentation Feasibility | **Content Quality:** Accuracy, Precision, Relevance. |
| | **Resource Availability:** Visual Support, Audio, Interactivity. |
| | **Ease of Access:** Accessibility, Device Compatibility. |
| | **Ease of Maintenance:** Updates, Technical Support. |
| Visual Feasibility | **Visual Quality:** Sharpness, Clarity, Color Consistency. |
| | **Design Consistency:** Stylistic Consistency, Suitability for Users. |
| | **Graphic Relevance:** Meaningfulness, Usage for Enhanced Understanding. |
| | **Graphic Accessibility:** Ease of Access, Suitability for User Needs. |

**Table 2.** Validation sheet for IMoART application (material expert)

| Aspect | Indicator |
|---|---|
| Description Feasibility | **Completeness of Literacy:** Element, Information. |
| | **Breadth of Literacy:** Cover, Scope, Topic. |
| | **Depth of Literacy:** Depth of Information. |
| Accuracy and Correctness | **Appropriateness of Learning Outcomes:** Relevance, Goals, Objectives. |
| | **Image and Object Accuracy:** Precision, Correctness. |
| | **Correctness of Literacy Material:** Accuracy, Details. |
| Learning Support Materials | **Technology Development:** Compatibility. |
| | **Latest Features:** Functionalities, up-to-date. |
| | **Linkage Between Concepts:** Coherence, Connection. |
| | **Literacy Enrichment:** Literacy skills. |

The media validation sheet and the material validation sheet are structured based on various aspects and indicators (see Table 1 and Table 2 for details). Table 3 categorizes the media validation based on the average score obtained, offering a comprehensive assessment of media performance.

**Table 3.** Media validation categories

| Score Average | Category | Decision |
|---|---|---|
| 4.51 < × > 5.00 | Very Good | Very Worthy |
| 3.51 < × > 4.50 | Good | Worthy |
| 2.51 < × > 3.50 | Average | Decent with repair |
| 1.51 < × > 2.50 | Poor | Unworthy |
| 1.00 < × > 1.50 | Very Poor | Very Unworthy |

To gather information on the practicality of the IMoART application, we administered a response questionnaire to students. It solicited feedback and opinions from students regarding the practicality of the IMoART application (see Table 4). Additionally, the criteria for evaluating the subject matter, as provided by experts, encompassed considerations for areas for improvement and suggestions to enhance the overall quality of the application.

**Table 4.** Practicality questionnaires indicators

| Aspect | Indicator |
|---|---|
| Ease of Use Navigation | The availability of clear and easy-to-understand menus or navigation. |
| | The ability of users to easily move between different pages or sections. |
| | Consistency in the layout and design of the navigation throughout the site or application. |
| | Intuitive use of icons or labels to identify important functions. |
| | Speed in responding to user actions, such as clicking or swiping. |
| Clarity | Easy understanding of the information presented, including text, images, and multimedia. |
| | Use of a language that is easy to understand and relevant to the target audience. |
| | The structure is well organized to avoid confusion and facilitate information retrieval. |
| | A lack of unnecessary distractions, such as annoying ads or unwanted pop-ups. |
| | Adherence to Web accessibility principles to ensure accessibility for all users, including those with disabilities. |
| Aesthetic | A visually appealing and aesthetically pleasing design. |
| | Harmony of design elements, such as color, typography, and layout. |
| | Use of images, graphics, or multimedia that enrich the visual experience. |
| | An overall look that is attractive and reflects the desired brand or purpose. |
| | Cleanliness and clarity of design that facilitates understanding of information. |
| Instructional Quality | Suitability of instructional material with the stated learning objectives. |
| | The logical and related organization of the material. |
| | Effective use of learning methods, such as illustrations, examples, or exercises. |
| | Use of appropriate language and communication for the target audience. |
| | Effective evaluation and feedback to aid understanding and learning progress. |

Table 5 outlines the categories to determine the practicality of the IMoART application based on the percentage of achievement rate.

**Table 5.** Media practicality categories

| No. | Achievement Rate (%) | Category |
|---|---|---|
| 1 | 85–100 | Very Practical |
| 2 | 75–84 | Practical |
| 3 | 60–74 | Practical enough |
| 4 | 55–59 | Less Practical |
| 5 | 0–54 | Not Practical |

## 3 RESULT AND DISCUSSION

This section explores the design results of the IMoART, including its key features, such as the AR menu, learning materials, instructional videos, and practice questions.

### 3.1 Design results

The design and development of the IMoART application involved four essential components: (1) an AR menu, (2) learning materials, (3) instructional videos, and (4) practice questions. We translated the analysis into a responsive interface design aimed at enhancing user engagement, combining aesthetic appeal with user-friendliness. The design process ensued from a comprehensive analysis of the application's requisites, ensuring alignment with user needs.

Upon launching the application, users were greeted with an engaging splash screen featuring the school logo and application name. Subsequently, users accessed the main menu, comprising buttons for (1) AR, (2) materials, (3) learning videos, (4) practice questions, and (5) exit. Figure 3 illustrates the main menu of the IMoART application.


**Fig. 3.** The main menu of an IMoART

When students clicked on the AR button, they were taken to the marker scanning page where they could view 3D representations of computer hardware introduction materials. Users could interactively rotate the 3D objects 360° to explore every angle, and this was accompanied by detailed explanations. Figure 4 illustrates the AR interface.


**Fig. 4.** AR feature interface of the IMoART application

The material menu provided students with informative text on hardware introduction, input devices, process devices, output devices, and storage devices. The content is aligned with the essential competencies and learning objectives required for junior high school students in the Indonesian context. Figure 5 depicts the display of the material menu.


**Fig. 5.** Material menu display of the IMoART application

The students were introduced to computer hardware concepts and additional material covering computer assembly. The videos presented were carefully sourced from YouTube to align with the content of the IMoART application. Figure 6 displays the video menu.


**Fig. 6.** Video menu of the IMoART application

The practice questions menu (see Figure 7) allowed students to evaluate their comprehension of hardware concepts presented in the IMoART application. Ten multiple-choice questions were posed to enhance the user experience, integrating theoretical knowledge with practical assessments, thereby reinforcing students' understanding of computer hardware.


**Fig. 7.** Practice questions of the IMoART application

## 3.2 Research results

**Expert validation results.** The validation results provided by experts are categorized into two main aspects: media and material, as elaborated in the preceding section. Three experts specializing in mobile application media conducted the evaluation of the media validation results, while three specialists in computer hardware learning material assessed the material validation results. Table 6 and Figure 8 present the detailed results of the media validation by media experts.

The expert media validation results demonstrate an average score of 3.68, positioning it within the 'Good' category. This suggests that the presentation technique, presentation feasibility, and visual feasibility received favorable ratings from media experts. Consequently, the final decision is considered 'Valid or Worthy.'

**Table 6.** Media expert validation results

| Aspect | Validator | Score | Category |
|---|---|---|---|
| Presentation Technique | Media Expert 1 | 3.61 | Good |
| | Media Expert 2 | 3.50 | Good |
| | Media Expert 3 | 3.63 | Good |
| Presentation Feasibility | Media Expert 1 | 4.31 | Good |
| | Media Expert 2 | 3.69 | Good |
| | Media Expert 3 | 3.64 | Good |
| Visual Feasibility | Media Expert 1 | 3.77 | Good |
| | Media Expert 2 | 3.53 | Good |
| | Media Expert 3 | 3.48 | Good |
| **Average Media Validation** | | **3.68** | **Good** |
| **Decision** | | **Worthy** | |

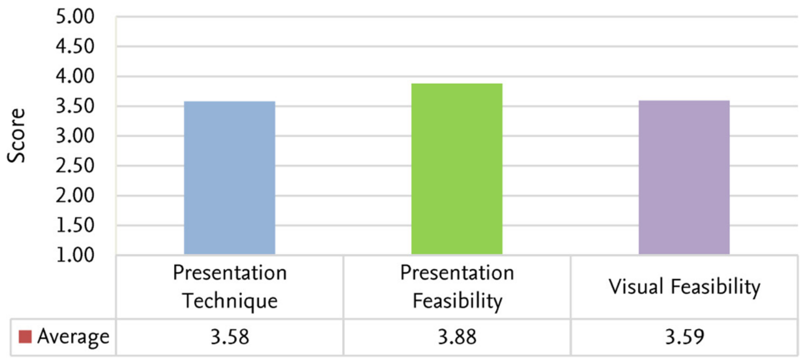


**Fig. 8.** Media expert validation results (average)

Table 7 and Figure 9 present the validation results provided by material experts, outlining assessments of three primary aspects: description feasibility, accuracy and truthfulness of the material, and learning support material. The material experts consistently awarded high scores for each aspect, culminating in an average material validation score of 3.81. This evaluation aligns with the 'Good' category, signifying favorable appraisals from material experts. Consequently, the final decision is considered 'Valid or Worthy.'

**Table 7.** Material expert validation results

| Aspect | Validator | Score | Category |
|---|---|---|---|
| Description Feasibility | Material Expert 1 | 3.77 | Good |
| | Material Expert 2 | 3.67 | Good |
| | Material Expert 3 | 3.84 | Good |
| Accuracy and Correctness of the material | Material Expert 1 | 4.01 | Good |
| | Material Expert 2 | 3.78 | Good |
| | Material Expert 3 | 3.79 | Good |
| Learning Support Materials | Material Expert 1 | 3.84 | Good |
| | Material Expert 2 | 3.80 | Good |
| | Material Expert 3 | 3.75 | Good |
| **Average Material Validation** | | **3.81** | **Good** |
| **Decision** | | **Worthy** | |

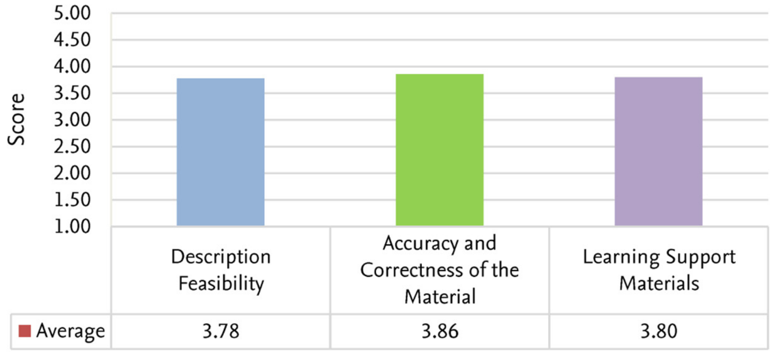


**Fig. 9.** Material expert validation results (average)

Based on these results, it can be concluded that the IMoART application successfully passed the validation stage of both media and material experts. This reinforces its credibility as a robust learning application and suggests that it is worthy of being utilized in computer hardware learning.

**Practicality results.** The practicality of the IMoART application was evaluated through assessments from teachers and students using a response questionnaire. The questionnaire was distributed after they had experienced using the IMoART application in the learning process. The results obtained from the response questionnaire are shown in Figure 10.

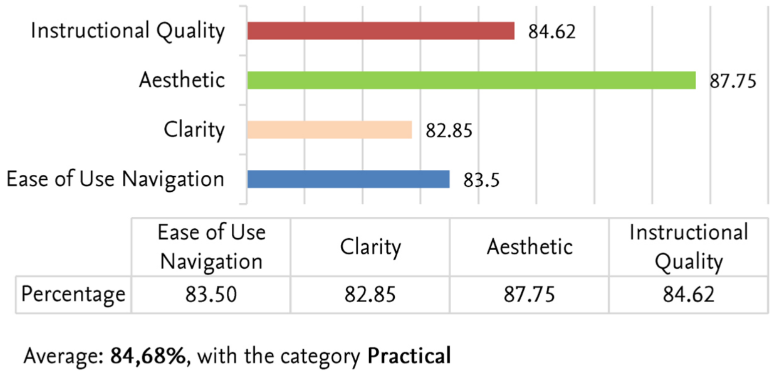


**Fig. 10.** Practicality results by aspect

The questionnaire responses provided valuable insight into the perceptions of both teachers and students regarding the application's usefulness and ease of use. The trial results revealed an average satisfaction rating of 84.68% under the criterion of 'Practical.' However, to gain a deeper understanding of the application's effectiveness and its alignment with users' needs and expectations in the context of learning, additional analysis was conducted.

Further analysis of the data involved examining specific feedback from participants and categorizing responses based on themes such as user experience, interface design, functionality, and educational impact. This qualitative analysis allowed for a nuanced understanding of the strengths and weaknesses of the application, highlighting areas for improvement and potential future enhancements.

Additionally, statistical analysis techniques such as correlation analysis and regression analysis were employed to identify any relationships between different variables, such as user demographics and satisfaction levels. This quantitative approach provided empirical evidence to support the qualitative findings and helped validate the overall conclusions drawn from the study.

By combining qualitative insights with quantitative data analysis, the research was able to provide a comprehensive evaluation of the application's performance and its suitability for use in educational settings. This thorough examination laid the groundwork for informed decision-making and potential adjustments to optimize the application for enhanced learning outcomes.

### 3.3 Discussion

This study reports on the significant potential of the IMoART application, developed for ICT subjects, as highlighted by material and media experts. The application effectively enhanced junior high school students' recognition and understanding of computer hardware. By incorporating 3D objects, videos, images, simulations, and interactive animations, the IMoART application offers students an engaging and efficient learning experience. It enables students to learn without spatial and temporal constraints, fostering creativity and independent learning.

These findings are in line with previous research that has used AR technology for educational purposes [33], [34]. However, earlier studies mainly focused on cognitive understanding, whereas this study focuses on both cognitive and engineering components. Specifically, it introduces high school juniors to computer hardware assembly and the psychomotor aspects of using computer hardware. It is possible that this application may also have an impact on students' emotions as they develop autonomy and self-regulatory learning habits.

The study aims to support educators and instructional designers in crafting more engaging and effective learning experiences. Integrating IMoART applications with artificial intelligence (AI) technology holds promise for enhancing education by improving learning accessibility, efficiency, and effectiveness, thus expanding learning opportunities for students globally. However, it is imperative to address privacy and ethical concerns when implementing this technology in education, as emphasized in references [35–39].

## 4 CONCLUSIONS

Several conclusions emerge from the findings of this study, addressing the research questions:

1. The IMoART application has been successfully designed, incorporating features such as an augmented reality menu, learning materials, instructional videos, and practice questions. Its responsive design ensures an attractive display and a user-friendly experience.
2. The validation results from media and subject matter experts indicate that IMoART received a 'Good' rating in categories such as presentation technique, presentation feasibility, visual feasibility, description feasibility, accuracy, truthfulness of the material, and learning support material. Therefore, it can be considered a valid or worthy application for learning tools.
3. The practicality evaluation was carried out using response questionnaires from teachers and students. IMoART has been shown to be effective in presenting material, aesthetically pleasing in terms of display, and robust in its ability to offer instructional quality according to the needs of the user, with an average percentage of 84.68% and the 'practical' criteria.

In conclusion, the IMoART application exhibits significant potential as an effective learning tool for computer hardware education. These findings offer valuable insights for refining technology-based learning applications, thereby enhancing students' overall learning experiences and comprehension.

Moving forward, there are promising opportunities for further development of IMoART. However, challenges such as infrastructure limitations and the need for teacher training to ensure the sustainability and success of implementing the application need to be addressed.

Fellow researchers are encouraged to focus on advancing the development of IMoART, adapting it for diverse educational contexts, and conducting comprehensive evaluations of its impact on student learning outcomes. By addressing these aspects collectively, we can contribute to the continuous improvement and effectiveness of technology-enhanced learning applications.

## 5 LIMITATIONS AND FUTURE WORK

It is important to acknowledge the limitations of this study. The sample size, while significant, is limited to a single educational institution and may restrict the broader applicability of the findings. Additionally, the use of IMoART may encounter constraints depending on specific contextual factors, such as learner aptitude, necessitating careful consideration when extrapolating results. External variables, such as cultural differences or educator efficacy, could impact the variability in research outcomes.

To assess the effectiveness of IMoART in diverse educational contexts, it is essential to explore its potential expansion into various subjects. A longitudinal analysis could provide lasting insights into the impact of IMoART on students' behavior and cognitive understanding. Investigating the integration of IMoART into formal curricula is essential for understanding its contributions to achieving educational objectives.

Moreover, future research could expand the scope to examine the relationship between IMoART and students' cognitive and emotional aspects, including motivational dynamics and heightened interest in the learning process. The examination of inclusivity dimensions, with a specific focus on how IMoART can contribute to inclusive learning environments, particularly for students with distinct needs, should be conducted carefully. Future research endeavors should be guided by a strong emphasis on enriching features within IMoART and enhancing interactivity and overall utility within the dynamic landscape of the learning paradigm.

## 6 AUTHORS CONTRIBUTIONS

**Agariadne Dwinggo Samala:** Formal Analysis, Methodology, Visualization, Supervision, Writing—original draft, Writing—review and editing. **Natalie-Jane Howard:** Formal Analysis, Validation, Writing—review and editing. **Santiago Criollo-C:** Formal Analysis, Writing—review and editing. **Ridho Dedy Arief Budiman:** Formal Analysis, Data Curation, Writing—original draft, Writing—review and editing. **Muhammad Hakiki:** Writing—review and editing. **Yayuk Hidayah:** Writing—review and editing.

## 7 REFERENCES


[1] J. M. Lewohl, "Exploring student perceptions and use of face-to-face classes, technology-enhanced active learning, and online resources," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 48, 2023. https://doi.org/10.1186/s41239-023-00416-3

[2] A. Monge Roffarello and L. De Russis, " 'Teaching and learning' digital wellbeing," *Future Generation Computer Systems*, vol. 149, pp. 494–508, 2023. https://doi.org/10.1016/j.future.2023.08.003

[3] A. D. Samala, R. Marta, S. Anori, and Y. Indarta, "Online learning applications for students: Opportunities & challenges," *Educational Administration: Theory and Practice*, vol. 28, no. 3, pp. 1–12, 2022. https://kuey.net/index.php/kuey/article/view/409

[4] F. Eliza, "Revolution in engineering education through android-based learning media for mobile learning: Practicality of mobile learning media to improve electrical measuring skills in the industrial age 4.0," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 20, pp. 60–75, 2023. https://doi.org/10.3991/ijim.v17i20.42093

[5] N. J. Howard, "Navigating blended learning, negotiating professional identities," *Journal of Further and Higher Education*, vol. 45, no. 5, pp. 654–671, 2020. https://doi.org/10.1080/0309877X.2020.1806214

[6] S. Cai, F.-K. Chiang, Y. Sun, C. Lin, and J. J. Lee, "Applications of augmented reality-based natural interactive learning in magnetic field instruction," *Interactive Learning Environments*, vol. 25, no. 6, pp. 778–791, 2017. https://doi.org/10.1080/10494820.2016.1181094

[7] H. Haerazi, I. M. P. Utama, and H. Hidayatullah, "Mobile applications to improve English writing skills viewed from critical thinking ability for pre-service teachers," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 14, no. 7, pp. 58–72, 2020. https://doi.org/10.3991/ijim.v14i07.11900

[8] A. D. Samala *et al.*, "Metaverse technologies in education: A systematic literature review using PRISMA," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 18, no. 5, pp. 231–252, 2023. https://doi.org/10.3991/ijet.v18i05.35501

[9] A. D. Samala, I. P. Dewi, and L. Mursyida, "'E-LabSheet project' 4Cs-based supplementary media for flexible learning: Is it well implemented?" *International Journal of Online and Biomedical Engineering (iJOE)*, vol. 19, no. 1, pp. 4–20, 2023. https://doi.org/10.3991/ijoe.v19i01.35523

[10] F. Herpich *et al.*, "How mobile augmented reality is applied in education? A systematic literature review," *Creat. Educ.*, vol. 10, no. 7, pp. 1589–1627, 2019. https://doi.org/10.4236/ce.2019.107115

[11] R. P. Mahendri, M. Amanda, U. Latifah, and S. Rawas, "Development of interactive flipbook-based e-module for teaching algorithms and basic programming in higher education," *J. Hypermedia Technol. Enhanc. Learn.*, vol. 1, no. 1, pp. 1–15, 2023. https://doi.org/10.58536/j-hytel.v1i1.18

[12] M. G. K. Ahsan, Miftahudin, and A. N. Cahyono, "Designing augmented reality-based mathematics mobile apps for outdoor mathematics learning," in *Journal of Physics: Conference Series*, 2020. https://doi.org/10.1088/1742-6596/1567/3/032004

[13] A. D. Samala, L. Bojic, D. Bekiroğlu, R. Watrianthos, and Y. Hendriyani, "Microlearning: transforming education with bite-sized learning on the go—insights and applications," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 21, pp. 4–24, 2023. https://doi.org/10.3991/ijim.v17i21.42951

[14] A. Kirkwood and L. Price, "Technology-enhanced learning and teaching in higher education: What is 'enhanced' and how do we know? A critical literature review," *Learn Media Technol.*, vol. 39, no. 1, pp. 6–36, 2014. https://doi.org/10.1080/17439884.2013.770404

[15] D. Sahin and R. M. Yilmaz, "The effect of augmented reality technology on middle school student's achievements and attitudes towards science education," *Comput. Educ.*, vol. 144, p. 103710, 2020. https://doi.org/10.1016/j.compedu.2019.103710

[16] A. D. Samala *et al.*, "Global publication trends in augmented reality and virtual reality for learning: The last twenty-one years," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 2, pp. 109–128, 2023. https://doi.org/10.3991/ijep.v13i2.35965

[17] A. D. Samala, F. Ranuharja, B. R. Fajri, Y. Indarta, and W. Agustiarmi, "ViCT—Virtual Campus Tour Environment with Spherical Panorama: A preliminary exploration," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 16, no. 16, pp. 205–225, 2022. https://doi.org/10.3991/ijim.v16i16.32889

[18] A. D. Samala, L. Bojic, D. Vergara-Rodríguez, B. Klimova, and F. Ranuharja, "Exploring the impact of gamification on 21st-century skills: Insights from DOTA 2," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 18, pp. 33–54, 2023. https://doi.org/10.3991/ijim.v17i18.42161

[19] A. D. Samala and M. Amanda, "Immersive Learning Experience Design (ILXD): Augmented reality mobile application for placing and interacting with 3D learning objects in engineering education," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 5, pp. 22–35, 2023. https://doi.org/10.3991/ijim.v17i05.37067

[20] E. Campos-Pajuelo, L. Vargas-Hernandez, F. Sierra-Liñan, J. Zapata-Paulini, and M. Cabanillas-Carbonell, "Learning the chemical elements through an augmented reality application for elementary school children," *Advances in Mobile Learning Educational Research*, vol. 2, no. 2, pp. 493–501, 2022. https://doi.org/10.25082/AMLER.2022.02.018

[21] D. Gormaz-Lobos, C. Galarce-Miranda, S. Kersten, and H. Hortsch, "Attitudes and perceptions of teaching staff about the online learning during the COVID-19 pandemic: A case study of engineering education," *International Journal of Engineering Pedagogy (iJEP)*, vol. 12, no. 3, pp. 38–49, 2022. https://doi.org/10.3991/ijep.v12i3.29947

[22] M. Kesim and Y. Ozarslan, "Augmented reality in education: Current technologies and the potential for education," *Procedia Soc. Behav. Sci.*, vol. 47, pp. 297–302, 2012. https://doi.org/10.1016/j.sbspro.2012.06.654

[23] P. H. Diao and N. J. Shih, "Trends and research issues of augmented reality studies in architectural and civil engineering education—A review of academic journal publications," *Applied Sciences 2019,* vol. 9, no. 9, p. 1840, 2019. https://doi.org/10.3390/app9091840
[24] C. Kwiatek, M. Sharif, S. Li, C. Haas, and S. Walbridge, "Impact of augmented reality and spatial cognition on assembly in construction," *Autom. Constr.*, vol. 108, p. 102935, 2019. https://doi.org/10.1016/j.autcon.2019.102935
[25] A. H. Hoti and K. Shatri, "The role and importance of ICT courses in improving the learning outcomes of pre-service teachers," *Academic Journal of Interdisciplinary Studies*, vol. 12, no. 3, pp. 327–335, 2023. https://doi.org/10.36941/ajis-2023-0081
[26] A. S. Azar and N. H. I. Tan, "The application of ICT Techs (Mobile-assisted Language Learning, Gamification, and Virtual Reality) in teaching English for secondary school students in Malaysia during COVID-19 pandemic," *Universal Journal of Educational Research*, vol. 8, no. 11C, pp. 55–63, 2020. https://doi.org/10.13189/ujer.2020.082307
[27] R. Gurevych, A. Silveistr, M. Mokliuk, I. Shaposhnikova, G. Gordiichuk, and S. Saiapina, "Using augmented reality technology in higher education institutions," *Postmodern Openings*, vol. 12, no. 2, pp. 109–132, 2021. https://doi.org/10.18662/po/12.2/299
[28] Z. Turan and G. Atila, "Augmented reality technology in science education for students with specific learning difficulties: Its effect on students' learning and views," *Research in Science & Technological Education*, vol. 39, no. 4, pp. 506–524, 2021. https://doi.org/10.1080/02635143.2021.1901682
[29] J. Quintero, S. Baldiris, R. Rubira, J. Cerón, and G. Velez, "Augmented reality in educational inclusion. A systematic review on the last decade," *Front. Psychol.*, vol. 10, p. 467496, 2019. https://doi.org/10.3389/fpsyg.2019.01835
[30] N. M. Alzahrani, "Augmented reality: A systematic review of its benefits and challenges in e-learning contexts," *Applied Sciences 2020,* vol. 10, no. 16, p. 5660, 2020. https://doi.org/10.3390/app10165660
[31] H. K. Wu, S. W. Y. Lee, H. Y. Chang, and J. C. Liang, "Current status, opportunities and challenges of augmented reality in education," *Comput. Educ.*, vol. 62, pp. 41–49, 2013. https://doi.org/10.1016/j.compedu.2012.10.024
[32] R. C. Richey and J. D. Klein, "Design and development research," *Handbook of Research on Educational Communications and Technology*, New York, NY: Springer New York, pp. 141–150, 2014. https://doi.org/10.1007/978-1-4614-3185-5_12
[33] Elida, Dony Novaliendry, Noper Ardi, Erni Marlina Binti Saari, and Nurindah Dwiyani, "Model development of android-based learning in vocational high school," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 22, pp. 152–159, 2023. https://doi.org/10.3991/ijim.v17i22.45403
[34] Jamaris, H. Hidayat, and A. P. Muji, "Mobile learning application: Effect of learning readiness and community learning toward technology management and mobile learning," *International Journal of Online and Biomedical Engineering (iJOE)*, vol. 17, no. 13, pp. 20–32, 2021. https://doi.org/10.3991/ijoe.v17i13.26871
[35] A. D. Samala, X. Zhai, K. Aoki, L. Bojic, and S. Zikic, "An in-depth review of ChatGPT's pros and cons for learning and teaching in education," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 18, no. 2, pp. 96–117, 2024. https://doi.org/10.3991/ijim.v18i02.46509
[36] S. Criollo-C, A. Guerrero-Arias, J. Guaña-Moya, A. D. Samala, and S. Luján-Mora, "Towards sustainable education with the use of mobile augmented reality in early childhood and primary education: A systematic mapping," *Sustainability*, vol. 16, p. 1192, 2024. https://doi.org/10.3390/su16031192

[37] A. Fortuna, Waskito, Purwantono, A. Kurniawan, W. Andriani, and M. Alimin, "Designing learning media using augmented reality for engineering mechanics course," *Journal of Engineering Researcher and Lecturer*, vol. 2, no. 1, pp. 18–27, 2023. https://doi.org/10.58712/jerel.v2i1.20
[38] Fajar Maulana, "Implementation of android learning media in the subject of machine elements: Analysis of needs and readiness," *J. Hypermedia Technol. Enhanc. Learn.*, vol. 1, no. 2, pp. 97–104, 2023. https://doi.org/10.58536/j-hytel.v1i2.70
[39] S. A. Mailando, I. P. Dewi, Hanesman, and A. D. Samala, "Interactive multimedia using Canva Application in basic electronics subject for grade X at SMK Negeri 1 Batipuh: A development study," *J. Hypermedia Technol. Enhanc. Learn.*, vol. 1, no. 3, pp. 126–138, 2023. https://doi.org/10.58536/j-hytel.v1i3.91
[40] F. Mufit, Y. Hendriyani, Usmeldi, M. Dhanil, and M. R. Tanjung, "The effectiveness of smartphone-based interactive multimedia integrated cognitive conflict models to improve 21st-century skills," *International Journal of Information and Education Technology*, vol. 13, no. 11, pp. 1793–1801, 2023. https://doi.org/10.18178/ijiet.2023.13.11.1991
[41] M. Hakiki, "Enhancing practicality of web-based mobile learning in operating system course: A developmental study," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 19, pp. 4–19, 2023. https://doi.org/10.3991/ijim.v17i19.42389

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