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Development of an Augmented Reality-Based E-Learning Module to Enhance Vocational Students' Collaborative and Communication Skills

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Abstract
This study aims to develop an Augmented Reality (AR)-based e-learning module intended to enhance vocational students' collaborative and communication skills. The study addresses the limited availability of interactive and engaging digital learning media that effectively support the development of 21st-century skills. The research adopted a Research and Development (R&D) approach utilizing the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Data were collected through questionnaires, observations, and interviews, and analyzed using both qualitative and quantitative methods. The product was validated by media and material experts, yielding an average score of 93,5%, categorized as very Valid. The results indicate that the developed AR-based e-learning module is effective in improving students' collaboration and communication skills and can serve as an innovative digital learning medium in vocational education.

Keywords: Augmented Reality, e-learning module, collaborative skills, communication skills, vocational education

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INTRODUCTION
The rapid development of digital technology has significantly transformed education, requiring adjustments in teaching and learning practices worldwide, including in vocational schools. In the context of 21st-century education, vocational students are expected to master not only domain-specific technical skills but also essential soft skills, such as collaboration, communication, critical thinking, and problem-solving. These skills are crucial for students' employability and success in modern workplaces (Supriyanto, Joshua, Abdullah, Tettehfio & Ramdani, 2023). However, many vocational schools still rely on traditional teacher-centered methods, emphasizing rote learning and repetitive exercises. Such approaches often fail to actively engage students or develop collaborative and communication skills,

leading to a gap between educational outcomes and the competencies demanded by contemporary industries (Kusuma & Yoto, 2024).

Recent studies highlight the importance of integrating interactive and technology-enhanced learning media to address these challenges. Among emerging technologies, Augmented Reality (AR) offers distinct advantages by overlaying digital information onto real-world environments, enabling students to interact with content in a more immersive and meaningful way. AR promotes visualization of abstract concepts, encourages active engagement, and facilitates collaborative learning, which is essential for developing soft skills in vocational education (Sabitri, Rahayu & Meirawan, 2024). Empirical evidence suggests that AR-based learning can improve both cognitive and non-cognitive outcomes. For example, Sabitri et al. (2024) found that AR-based flipbooks enhanced vocational students' critical thinking and collaboration skills, while Ramadhan, Rohendi, Handayani, and Abdullah (2023) reported that AR supports technical skill acquisition alongside teamwork and problem-solving abilities.

Despite these promising results, the use of AR in vocational education remains limited, especially concerning structured and validated e-learning modules that explicitly aim to develop collaboration and communication skills. Most existing studies focus on individual learning outcomes, technical competencies, or motivation, neglecting the systematic cultivation of essential soft skills through interactive digital media (Supriyanto et al., 2023). Moreover, many AR learning tools lack rigorous instructional design and validation, raising concerns about their pedagogical effectiveness, usability, and scalability. In short, although prior research shows the potential of AR, there is a clear need for comprehensive, validated modules that simultaneously develop technical competencies and 21st-century soft skills.

The originality of this study lies in its combination of AR technology with systematic instructional design to produce a validated, interactive e-learning module specifically designed to enhance collaboration and communication skills in vocational students. Unlike previous research that mainly focused on cognitive or technical outcomes, this study emphasizes team-based, interactive learning experiences that cultivate essential soft skills, addressing both technological and pedagogical dimensions of vocational education. By synthesizing prior studies and identifying their limitations, this research directly addresses the lack of interactive AR-based media for collaboration and communication skill development.

Accordingly, this research develops an AR-based e-learning module using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), ensuring both pedagogical rigor and technological innovation (Dick, Carey & Carey, 2015). The study evaluates the module's feasibility through expert validation and its effectiveness in improving students' collaboration and communication skills in authentic classroom settings. Integrating AR with structured instructional design is

expected to create an immersive, engaging, and pedagogically sound learning environment that promotes the simultaneous development of technical and soft skills.

In conclusion, this research is significant because it addresses critical challenges in vocational education by developing an innovative, evidence-based learning medium that enhances essential 21st-century skills. The study contributes to the application of AR in education and provides practical guidance for curriculum development, teaching strategies, and digital media integration in vocational schools. By explicitly targeting collaboration and communication skills, the developed AR-based e-learning module bridges the gap between traditional vocational practices and the competencies required in modern workplaces, supporting students' holistic development and improving the overall quality of vocational education

METHOD

This study employed a Research and Development (R&D) design using the ADDIE model, conducted at SMK Negeri 1 Gempol with participants from grade XI TPTP 1 and XI TPTP 2. The product developed was an Augmented Reality (AR)-based e-module for the Air Conditioning (AC) Split Installation course.

Data were collected using multiple methods, including classroom observation, questionnaires, interviews, expert validation, collaborative skill assessments, communication skill assessments, and student feedback. The development process followed the five stages of the ADDIE model: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation.

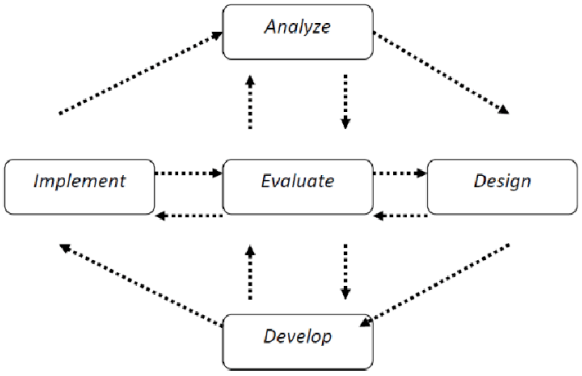

Fig 1. Research and Development Procedure Based on the ADDIE Model

During the Analysis stage, student needs, learning objectives, and classroom context were identified. The Design stage involved planning instructional strategies, learning scenarios, and assessment instruments. In the Development stage, the e-module was created, validated by experts, and revised based on feedback from a small-scale trial. The Implementation stage consisted of applying the e-module in the classroom to measure its effectiveness in improving collaboration and

communication skills. Finally, the Evaluation stage assessed the product's validity, practicality, and effectiveness based on expert ratings and student responses.

RESULTS AND DISCUSSION

Augmented Reality-Based E-Module Development Process

The development of the Augmented Reality (AR)-based e-module was carried out through five systematic stages following the ADDIE model, namely analysis, design, development, implementation, and evaluation. In the initial stage, the researcher conducted a comprehensive analysis to identify learning needs, student characteristics, learning objectives, and the learning environment. The results of semi-structured interviews and classroom observations at SMKN 1 Gempol indicated that students experienced difficulties in understanding the material on air conditioning installation systems, particularly on the topic of AC Split installation. These difficulties arose due to the limited use of instructional media capable of visualizing the cooling system process in depth. Therefore, the development of an AR-based e-module was considered necessary to facilitate students' understanding of abstract technical concepts through more interactive and visual learning experiences.

The analysis of student characteristics showed that class XI TPTP students, who have a vocational background emphasizing practical skills, tend to learn more effectively through visual and hands-on approaches rather than lecture-based learning. Moreover, the students demonstrated a high level of familiarity with digital devices, suggesting that the integration of AR technology in the e-module would be appropriate and engaging. The learning objectives identified from the SITU curriculum focused on students' ability to understand the working principles of air conditioning systems, identify the main components of AC Split units, and plan and perform installation correctly and safely. In addition, the learning environment analysis revealed that SMKN 1 Gempol was equipped with adequate laboratory facilities and internet access, yet the utilization of digital media in teaching remained limited. This condition strengthened the rationale for developing an AR-based e-module as an innovative medium to enhance learning engagement and comprehension.

The second stage was the design phase, which focused on planning the instructional strategies, learning scenarios, media elements, and assessment instruments to be used in the development process. The learning strategy applied in this study emphasized a student-centered approach that encouraged active participation, collaboration, and communication among students. The learning scenario was structured systematically into the introduction, core, and closing activities, all integrated with the use of the AR-based e-module in the SITU subject. The media design was adjusted to the applicable curriculum and developed using digital components such as text, images, videos, and 3D visualizations to display the

structure and working mechanism of air conditioning systems more clearly. Several instruments were also prepared to measure the feasibility and effectiveness of the product, including expert validation sheets, student response questionnaires, and collaborative and communication skill assessments.

In the third stage, the development phase, the AR-based e-module was created based on the design results using appropriate digital software that allowed the integration of multimedia and AR elements. The main interface of the AR-based e-module consists of an interactive menu layout that facilitates user navigation and access to learning materials. Figure 2 presents the main interface of the developed e-module.

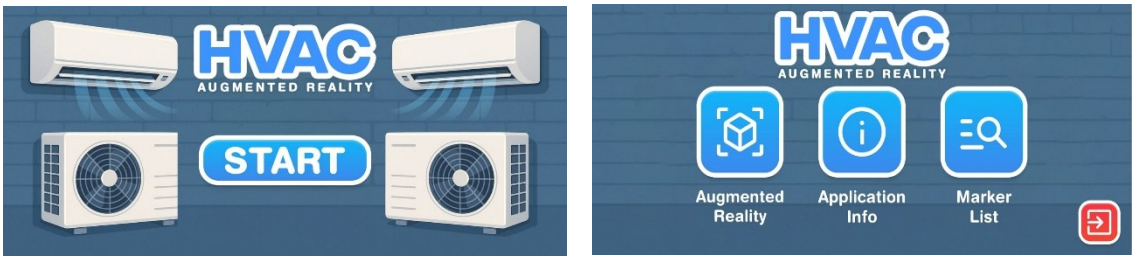

Fig 2. *Main interface of the AR-based e-module showing navigation and menu layout*

The initial product underwent validation by media and material experts to ensure content accuracy, language clarity, display quality, and alignment with learning objectives. Revisions were made based on the experts' feedback to improve the quality and validity of the product. After validation, a small-group trial was conducted involving ten students from class XI TPTP 1 to test the clarity, usability, and attractiveness of the e-module. The trial results indicated that the AR-based e-module was easy to use, visually engaging, and helpful in understanding technical concepts. One of the main features of the e-module is the visualization of AC Split components in 3D using Augmented Reality, allowing students to explore system parts interactively. Figure 3 illustrates the visualization of AC Split components through Augmented Reality

Fig 3. *Visualization of AC Split components through Augmented Reality.*

Subsequently, a practicality test was carried out involving both teachers and students to assess usability, appeal, and learning engagement, with the results

showing that the e-module was highly practical and ready for classroom implementation.

The fourth stage, the implementation phase, involved applying the validated e-module in a real classroom setting to examine its effectiveness. The implementation was carried out in class XI TPTP of SMKN 1 Gempol with the SITU subject teacher acting as a facilitator. Students used the AR-based e-module to explore AC Split components, observe system operations through augmented visualizations, and collaborate in groups to complete problem-solving tasks. During classroom implementation, students actively interacted with the AR-based e-module using their mobile devices during group learning sessions. Figure 4 shows students interacting with the e-module during classroom implementation.

Fig 4. *Students interacting with the AR-based e-module during classroom implementation*

The evaluation results demonstrated that students' collaborative and communication skills improved after using the e-module, as evidenced by the comparison of pre- and post-learning assessments obtained through self-evaluation questionnaires, observation sheets, and reflective interviews.

The final stage was the evaluation phase, which aimed to assess the overall quality and effectiveness of the developed product. Formative evaluations were conducted throughout the analysis, design, development, and implementation stages to continuously refine the e-module based on expert and user feedback. Summative evaluation was performed after implementation to determine the e-module's effectiveness in enhancing collaboration and communication skills. The findings showed that the AR-based e-module fulfilled the criteria of validity, practicality, and effectiveness, and could therefore be recommended as an innovative learning medium for the Sistem Instalasi Tata Udara subject. The product is expected to serve as an alternative instructional resource to support technical learning in vocational education, particularly in topics requiring visual and practical comprehension.

Media Feasibility Assessment

The feasibility of the AR-based e-module was evaluated by one media expert and two material experts. The results of the assessment are presented in Table 1, showing that the e-module meets the criteria for quality, clarity, and alignment with learning objectives.

Table 1. Media Feasibility Assessment Results

Validation	Media Expert	Material Expert
Score	60	67
Presentation	93,7%	93,1%
Cattegory	Very Valid	Very Valid

The feasibility of the AR-based e-module was evaluated through validation conducted by experts, comprising one media expert and two material experts. The media expert assessment yielded a total score of 60, corresponding to a percentage of 93.7%, categorized as Very Valid. Meanwhile, the material experts obtained a total score of 67, resulting in a percentage of 93.1%, also categorized as Very Valid.

The validation scores from the media and material experts were combined to determine the overall product validity. Based on this calculation, the AR-based e-module obtained an overall score of 93.5%, indicating that it can be classified as Very Valid according to the established assessment criteria.

These validation results indicate that both the media and content of the AR-based e-module meet the criteria for quality, clarity, and alignment with learning objectives. The findings demonstrate that the e-module is highly suitable for classroom implementation, providing accurate instructional content and an engaging learning experience. This outcome is consistent with previous studies showing that well-validated learning media effectively support students comprehension of technical concepts and enhance practical skills.

Media Attractiveness Assessment

The attractiveness of the AR-based learning module was assessed through student response questionnaires distributed to 35 participants who used the product during the learning process. The questionnaire aimed to measure students perceptions of the module's visual design, content presentation, interactivity, usability, and overall learning experience. The summarized results of the student responses are presented in Table 2.

Table 2. Media Attractiveness Assessment Results

Aspect	Student Response
Score	3,5
Presentation	88,4%
Cattegory	Very Good

Based on the collected data, the AR-based e-module achieved an average score of 3.5 (88.4%), categorized as very good. This indicates that students responded positively to the module, particularly appreciating its engaging design, clear visualizations, and the integration of Augmented Reality features, which enhanced their understanding of the air conditioning installation system. The interactive 3D elements allowed students to observe the structure and working mechanism of AC Split systems in a realistic manner, increasing motivation and participation during learning activities.

Feedback also showed that the module was easy to operate, accessible across various devices, and provided meaningful learning experiences that supported both independent and collaborative learning. No major suggestions for improvement were reported, indicating that the module met students' expectations regarding design and functionality.

These findings demonstrate that the AR-based e-module not only meets technical and pedagogical requirements but is also highly attractive and engaging for users. This is consistent with previous studies highlighting that interactive, technology-integrated learning media can enhance student engagement and comprehension, particularly in vocational education settings where practical understanding is essential. Mohamad et al., (2024) reported that integrating AR in vocational learning modules increased students' motivation and active participation. Similarly, Anuar et al., (2021) found that AR-based instructional materials improved students' learning motivation and understanding of complex technical concepts. Furthermore, Alfian, Khumaedi, and Sutopo., (2024) confirmed that AR-Card learning media enhanced student engagement and learning outcomes. These consistent findings support the effectiveness of the AR-based e-module developed in this study as an engaging and effective learning tool for vocational education.

Media Effectiveness Assessment

The effectiveness of the AR-based e-module was evaluated to determine its impact on students' collaboration and communication skills. The assessment employed pretest and posttest instruments administered to both control and experimental groups, each consisting of 35 students. The summary of the average results is presented in Table 3 and Table 4.

Table 3. Pretest Assessment Results of Media Effectiveness

Aspect	Collaboration skill Class Control	Communication Skill Class Control	Collaboration skill class Experimental	Communication skill class Experimental
Score	2,15	2,18	2,25	2,27
Presentation	53.75%	54.50%	56.25%	56.75%
Cattegory	Fairly Active	Fairly Active	Fairly Active	Fairly Active

Table 4. Postest Assessment Results of Media Effectiveness

Aspect	Collaboration skill Class Control	Communication Skill Class Control	Collaboration skill class Experimental	Communication skill class Experimental
Score	2,52	2,58	3,45	3,38
Presentation	63.00%	64.50%	86.25%	84.50%
Cattegory	Active	Active	Highly Active	Highly Active

The findings reveal a substantial improvement in both collaboration and communication skills among students in the experimental group compared to the control group. The experimental group's collaboration score increased from 56.25% (Fairly Active) to 86.25% (Highly Active), while communication improved from 56.75% to 84.50%. Meanwhile, the control group demonstrated only moderate gains, reaching 63.00% and 64.50%, respectively.

These results indicate that the integration of Augmented Reality within the learning module effectively enhances students' cooperative and communicative competencies. The immersive 3D features facilitated dynamic interaction, active discussion, and realistic visualization of technical concepts leading to greater engagement and participation during the learning process.

This finding aligns with Rahman et al., (2023), who emphasized that AR-based interactive media significantly improves vocational students' soft skills and learning engagement. Similarly, Yuliani and Prasetyo., (2022) reported that the implementation of AR-integrated modules effectively strengthens communication and collaboration skills through immersive learning experiences.

CONCLUSION

This study successfully developed an Augmented Reality-based e-module for the Air Conditioning Split Installation course at SMKN 1 Gempol, designed to enhance vocational students' collaboration and communication skills. The module was developed using the ADDIE model, ensuring systematic instructional design, pedagogical rigor, and effective technology integration. Expert validation indicated high feasibility, with an overall score of 93.5%, classified as very valid, confirming the module's suitability for classroom implementation.

Student responses demonstrated a high level of attractiveness and usability, with an average score of 88.4%. The results highlight the module's engaging design, interactive three-dimensional visualizations, and effective integration of Augmented Reality, supporting both independent and collaborative learning activities.

Effectiveness assessment showed significant improvements in the experimental group, with collaboration scores increasing from 56.25% to 86.25% and communication scores from 56.75% to 84.50%, compared to moderate gains in

the control group. These findings indicate that the AR-based e-module effectively promotes active participation, teamwork, and communication skills, contributing to the development of essential 21st-century soft skills among vocational students.

In conclusion, the AR-based e-module not only facilitates the understanding of technical concepts in AC Split systems but also effectively develops collaboration and communication skills. The study provides evidence that integrating Augmented Reality with structured instructional design can bridge the gap between traditional vocational teaching practices and the competencies required in modern workplaces, offering a practical, engaging, and effective learning medium for vocational education.

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