BIS HUMANITIES AND SOCIAL SCIENCE

Volume 4 2026 | DOI: 10.31603/bishss.427
7th Borobudur International Symposium on Humanities and Social Science (BIS-HSS) 2025

UNIMMA PRESS
Universitas Muhammadiyah Magelang

Mobile augmented reality for vocational education learning "marvel": Innovation of mobile augmented reality learning media as a practical and effective solution in vocational education

Nuzul Hidayat[1*], Wakhinuddin[1], Remon Lapisa[1], Wawan Purwanto[1], Hendra Hidayat[1], Riki Mukhaiyar[1], Gunawarman[2], Jackly Muriban[3], and Desi Yusdian[4]

[1] Universitas Negeri Padang, Padang, Indonesia
[2] Universitas Andalas, Padang, Indonesia
[3] Centre for Research and Innovation, Jabatan Pendidikan Politeknik dan Kolej Komuniti, Malaysia
[4] Sharia Economic Law (HES) UIN Mahmud Yunus Batusangkar, Batusangkar, Indonesia
[*]Corresponding author's email: nuzulhidayat@ft.unp.ac.id

Abstract

This research focuses on the development of Mobile Augmented Reality for Vocational Education Learning (MARVEL) as an interactive learning medium for introducing components of Air Conditioning Technology in vocational education. MARVEL is designed to enhance learning experiences by integrating Augmented Reality (AR) technology, allowing students to visualize 3D models of system components through a mobile application. The research follows a Research and Development (R&D) methodology, including needs analysis, design, development, validation, and evaluation. Expert validation was conducted by subject matter experts, media experts, and teachers, with assessments covering aspects such as content feasibility, presentation, language, interface design, software engineering, usability, and compatibility. The results indicate that MARVEL received high feasibility ratings: 92.72% from subject matter experts, 92.4% from media experts, and 96.8% from teachers, classifying it as "excellent." These findings suggest that MARVEL is an effective, engaging, and innovative learning tool that enhances students' understanding of Air Conditioning Technology. By incorporating interactive AR-based content, MARVEL improves conceptual visualization and practical knowledge, making it a valuable addition to vocational education. Future research can focus on expanding content, improving interactivity, and testing in real classroom settings to further enhance its impact.

Published:
May 04, 2026

Selection and Peer-review under the responsibility of the 7th BIS-HSS 2025 Committee

Keywords

Mobile augmented reality, Vocational education, Air conditioning technology, Interactive learning, Educational technology

Introduction

Vocational education plays a crucial role in preparing skilled workers who are ready to compete in the industry. However, one of the main challenges in vocational education is the lack of interactive learning media that align with the needs of modern industries [1]. In this context, Mobile Augmented Reality (MAR) technology offers an innovative solution to enhance the learning experience of vocational students.

Augmented Reality (AR) is a technology that enables users to interact with virtual objects projected into the real world through mobile devices (Azuma, 1997). This technology has been proven to increase learning motivation and comprehension of complex concepts [2]. In vocational education, MAR can be used to simulate complex work processes and enhance students' practical skills [3].

However, the implementation of MAR technology in vocational education still faces several challenges, such as the lack of media development tailored to specific course requirements and limited access to the technology [4]. Therefore, the development of MAR-based learning media called "MARVEL" (Mobile Augmented Reality for Vocational Education Learning) is expected to address these issues.

The study of air conditioning technology typically begins with the fundamental introduction of air conditioning system components in automobiles. The next stage involves a deeper understanding of its working principles and the analysis of system performance, from basic operations to more complex mechanisms [5]. The components of an air conditioning system serve as essential elements that support its functionality. These components include the compressor, condenser, receiver dryer, expansion valve, evaporator, and other related parts [6].

The course, Air Conditioning Technology, includes basic competencies related to the introduction of fundamental electronic components [7]. These competencies cannot be effectively explained through traditional lecture methods or static images alone [8]. Based on interviews and the author's experience, the conventional methods of lecturing and using images have limited impact on students' comprehension of air conditioning technology concepts.

A similar issue was identified in another study by [9], which found that existing training media still have limitations, particularly in terms of introducing air conditioning system components comprehensively. Additionally, previous research-developed media cannot be widely implemented in schools due to constraints in their development and distribution.

Thus, to effectively learn air conditioning technology, a supplementary learning tool is needed that can visualize components comprehensively while remaining accessible and user-friendly for both teachers and students [10]. According to [11], students gain more meaningful learning experiences when they study material in a concrete manner rather than in an abstract way. However, direct hands-on experience can be challenging to

implement in the learning process since not all concepts can be taught through direct exposure.

According to [12], learning media play a crucial role in facilitating the teaching and learning process. Instructional media are essential in overcoming learning barriers, making educational content more accessible and understandable for students. The presence of effective learning media supports a more efficient learning process and helps educators achieve instructional objectives more effectively.

With advancements in information technology, individuals can now use devices such as smartphones, laptops, or computers to identify components in learning [13]. The development of Augmented Reality on smartphones will assist students in recognizing air conditioning system components [14].

The study by [15] introduced the concept of merging real and virtual objects into a three-dimensional (3D) interactive environment in real time. The concept of Augmented Reality (AR) is an evolution of Virtual Reality (VR) or Virtual Environments (VE). Unlike VR, which immerses users in a fully synthetic environment, AR enhances the real world by overlaying digital content. Today, AR technology has advanced significantly and can now integrate video elements as well.

From a technical perspective, AR is a transformative technology that extends interaction beyond the screen [16]. Strategically, the use of AR-based instructional tools significantly enhances the teaching and learning process by incorporating engaging and interactive elements. AR technology provides a unique visual representation that captures students' interest and facilitates a more concrete understanding of complex concepts [17][18].

With AR technology, modern advancements can address various challenges, making learning materials more engaging and visually clear [19]. For this reason, the author aims to integrate AR with Android-based smartphones to provide a comprehensive representation of electronic components and fundamental electronics. AR is an attractive tool that allows users to perform complex tasks in learning environments [20].

The introduction of MARVEL is designed to enhance students' conceptual understanding of Air Conditioning Technology in the automotive field. This media not only provides an immersive visual experience but also enables students to interact directly with machine components through AR technology [21].

This study aims to develop and test the effectiveness of MARVEL in improving vocational students' learning outcomes. The research primarily focuses on media design, expert validation, and real-world student trials. Thus, the development of MARVEL is expected to make a significant contribution to enhancing the quality of learning in vocational education, particularly in the Air Conditioning Technology course in the automotive sector.

Method

In the Air Conditioning Technology course at the Department of Automotive Engineering, Faculty of Engineering, Universitas Negeri Padang, this research aims to develop an interactive learning medium that students can use for self-directed learning.

A research and development (R&D) approach is employed to design this three-dimensional model. The research and development method is used to create specific products and test their effectiveness. This method differs from other educational research methods because its primary objective is to develop products through trial and revision before producing a feasible final product. Research and development is a process used to develop and validate educational and learning materials, as stated by [22] in [23].

Development steps

According to [24], the general steps of research and development shown in Figure 1.

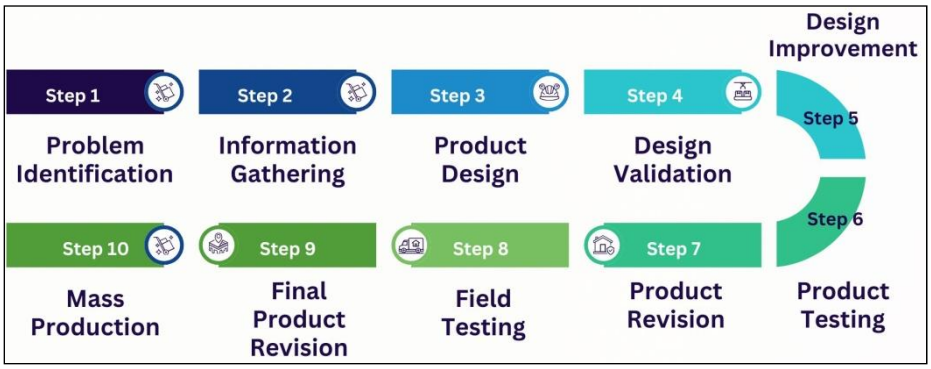

Figure 1. Research development steps

Problem identification

At this stage, the identified problem should offer value when addressed. The problem must be based on empirical data, which may come from research reports, studies conducted by others, or reports from institutions or individuals.

1. Information gathering

   Once the problem is accurately and currently identified, various information sources are collected to support the planning of a specific product designed to solve the issue. This requires specialized research methods.

2. Product design

   The outcomes of research and development vary. One way to describe a product design is through diagrams or charts that assist in assessment and development. Alternatively, it may be a system accompanied by an explanation of its usage, functionality, advantages, and disadvantages.

3. Design validation

   This process aims to determine whether the new product design will be more effective than the existing one. The evaluation is rational, as it is still based on

logical reasoning without field data considerations. Experts in the relevant field are invited to assess the product and discuss its strengths and weaknesses. For instance, in research on learning model and instructional material development, experts in the subject matter and educational technology, as well as learning evaluation specialists, may be involved.

4. Design improvement

   Once the product's weaknesses are identified, design revisions are carried out. Researchers responsible for product development are tasked with refining the design.

5. Product testing

   The initial stage of product testing involves simulating its use. After simulation, testing is conducted on a small group of users to determine whether the new product is more effective than the previous version.

6. Product revision

   Since initial testing is limited, it may not fully reflect real-world conditions. During this stage, weaknesses and shortcomings of the product are identified, allowing users to provide feedback and gather data on its performance.

7. Field testing

   After revisions, the product is tested on a larger population. Continuous evaluation is necessary to identify weaknesses and improve the product accordingly.

8. Final product revision

   If performance issues arise when used by a broader audience, developers must reassess and refine the product. Evaluation results help enhance the existing product or lead to the development of a new one.

9. Mass production

   This is the final stage of research and development. Once the product has proven successful through multiple tests, it can be mass-produced for widespread implementation. Techniques such as surveys, quasi-experiments, and action research help ensure the validity and credibility of the study.

Instrument

1. Observation

   Observation is an action carried out by individuals who are knowledgeable about a phenomenon, using prior knowledge and established concepts to obtain the necessary information for further research. In this study, the observation technique is used to observe and interview lecturers of the Air Conditioning

Technology course to gain insights into the module product that will be developed.

2. Questionnaire

The questionnaire is used to collect the necessary data for the research objectives. Suggestion and comment sheets, along with questionnaires, serve as research tools.

Table 1. Instrument grid for subject matter experts

No.	Aspect	Indicator
11	Content Feasibility (CF)	Alignment of material with curriculum standards Material accuracy Supporting learning materials Material relevance and up-to-date content
22	Presentation Feasibility (PF)	Presentation technique Supporting presentation Learning presentation Completeness of presentation
33	Language Assessment (LA)	Clarity Communicative Dialogic and Interactive Suitability with student development level Coherence and logical flow Use of terms, symbols, or icons

Table 2. Instrument grid for media experts

No	Aspect	Indicator
		For MARVEL Application
1	Display Quality (DQ)	Suitability of icons, layout, and page layout Menu and material display presentation Font and color suitability
2	Software Engineering (SE)	Ease of application operation
3	Usability (U)	Application usage
4	Interface (I)	Design matches user level Format and image resolution suitability
5	Reusable (R)	Future media development
6	Maintainable (M)	Ease of application installation and compatibility with other software
7	Compatibility (C)	Application compatibility with Android smartphones
		For Learning Modules
1	Graphic Feasibility (GF)	Module physical size Module cover layout Attractive and easy-to-read font Module cover illustration Layout consistency Harmonious layout size Complete layout elements Layout supports understanding Consistent typography Easy-to-read typography Content illustration

A questionnaire is a collection of written questions designed to obtain information from respondents regarding what they know or about themselves [25]. There are assessment forms for experts and specialists, as well as assessment forms for lecturers and students.

The evaluation method for the feasibility of the learning module uses a Likert scale with response options consisting of very good, good, fair, poor, and very poor. The scores assigned to these responses are: Very good = 5, Good = 4, Fair = 3, Poor = 2, Very poor = 1.

The questionnaire instrument is divided into four categories: subject matter experts, media experts, lecturers of the Air Conditioning Technology course, and users (students). The instrument provided to subject matter experts aims to assess whether the content presented in the learning media aligns with competency standards, basic competencies, and the expected indicators. The instrument grid for subject matter experts is presented in Table 1. Next, the researcher uses media expert instruments to assess the learning media in terms of its relevance and suitability for students. The instrument grid for media experts is presented in Table 2.

Development procedure

According to [26], a procedure is a series of actions that must be carried out step by step to achieve a specific goal or complete a product. In this study, the researcher seeks to align the learning development procedure with the following steps as presented in Figure 2.

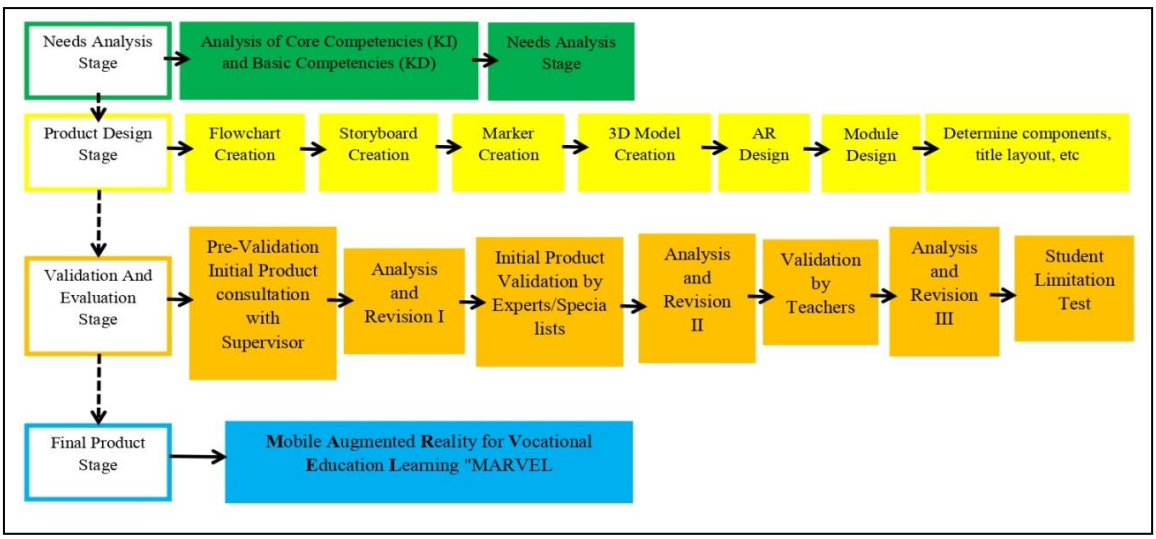

Figure 2. Development procedure MARVEL

Flowchart

The flowchart image shows the structure of the sequence of activities of a program from beginning to end. The flowchart of the MARVEL application developed by the researcher is as follows:

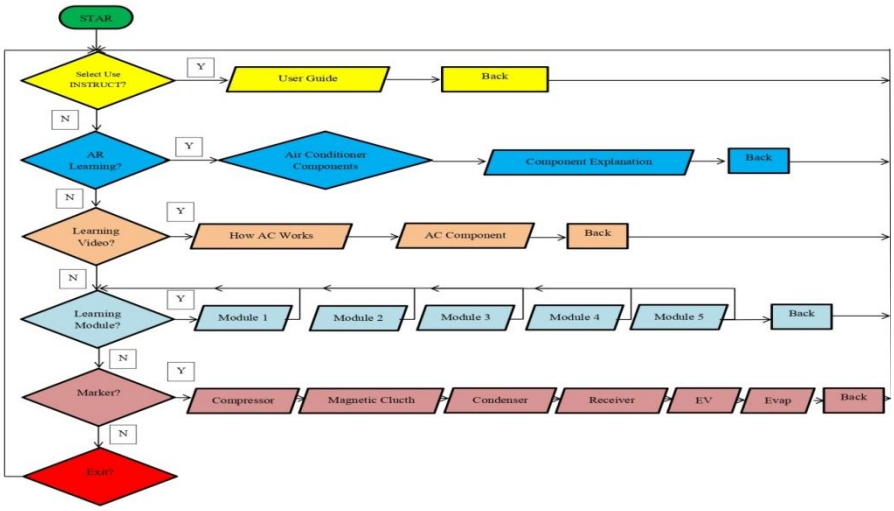

Figure 3. Flowchart MARVEL

Figure 3 shows the main page of the application interface, where users can access instructions, download modules, select materials, and exit the application. Additionally, users can read and learn how to use the MARVEL application, as well as download the module directly. After downloading the module, or if they already have it, users will be directed to the material page. On this page, they can choose the learning material they want. In AR Learning, users will be taken to camera mode after making a selection. This mode allows the camera to scan module markers and display 3D objects detected by the camera.

Results and discussion

Results

1. Storyboard

   One alternative way to integrate storytelling and visuals into the application we are developing is by creating a storyboard. Below is the storyboard design for the 3D application. One alternative way to integrate storytelling and visuals into the application is by creating a storyboard. The storyboard design for the 3D application is presented in Figure 4.

Figure 4. MARVEL Application Media View

After the storyboard stage, the application was developed into marker-based augmented reality learning media. Figure 5 shows the markers and MARVEL scan results used to display 3D components of the air conditioning system.

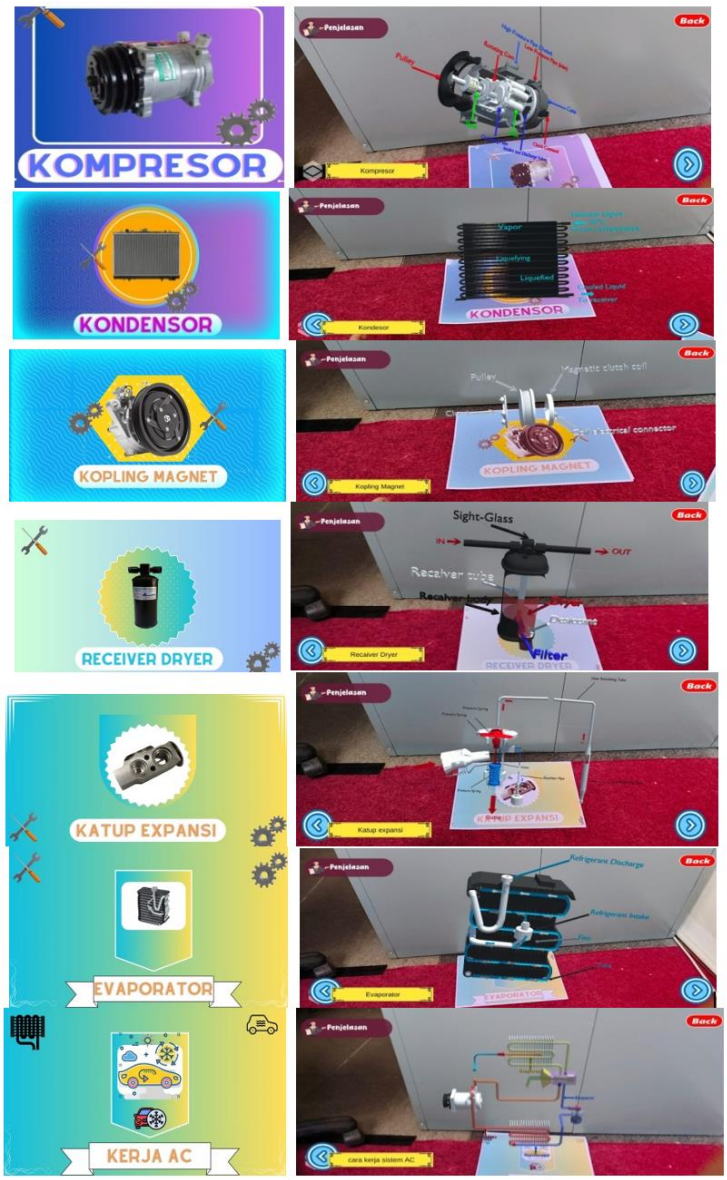

Figure 5. Marker and MARVEL scan results

2. Validation by subject matter expert

The material validation process is necessary to ensure that the taught material aligns with the Core Competencies, Basic Competencies, and Indicators of the Air Conditioning Technology course in the Automotive Engineering program at the Faculty of Engineering, Universitas Padang. After the expert reviews all the material in the learning media, the evaluator can answer the questions in the prepared questionnaire. The data is then thoroughly analyzed for each component, as presented in Table 3.

Table 3. Assessment of content suitability aspects by material experts

Assessment Indicator	Assessment Items	Score	Interpretation
A. Material suitability with KI and KD	1. Completeness of material	4	Good
	2. Scope of material	5	Very Good
	3. Depth of material	4	Good
B. Material accuracy	4. Accuracy of concepts and definitions	5	Very Good
	5. Accuracy of principles	4	Good
	6. Accuracy of facts and data	5	Very Good
	7. Accuracy of examples	5	Very Good
	8. Accuracy of questions	5	Very Good
	9. Accuracy of images, diagrams, and illustrations	5	Very Good
	10. Accuracy of notation, symbols, and units	5	Very Good
	11. Accuracy of references	5	Very Good
C. Learning material support	12. Reasoning	4	Good
	13. Coherence	5	Very Good
	14. Communication (write and talk)	5	Very Good
	15. Application	5	Very Good
	16. Material attractiveness	5	Very Good
	17. Encouraging further information retrieval	5	Very Good
D. Material update	18. Suitability of material with scientific developments	5	Very Good
	19. Images, diagrams, and illustrations	4	Good
	20. Updated references	4	Good
Total		90	Very good

According to the data in Table 3, the subject matter expert's assessment of the content feasibility aspect in the development of this learning media received a score of 90. When converted into a percentage, this results in a value of 90%, with an interpretation of "very good."

According to the data available in Table 4, the subject matter expert's assessment of the material presentation element in the development of this learning media received a score of 54. When converted into a percentage, it results in a value of 98.18%, with an interpretation of "very good."

Table 4. Assessment of presentation aspect by subject matter expert

Assessment Indicator	Assessment Items	Expert Score	Interpretation
Presentation Technique	1. Consistency of systematic presentation in learning activities	5	Very Good
	2. Sequence of presentation	5	Very Good
	3. Feedback on practice questions	5	Very Good
Presentation Support	4. Selection of AR images	5	Very Good
	5. Introduction	4	Good
	6. References	5	Very Good
	7. Summary	5	Very Good
Learning Presentation	8. Student involvement	5	Very Good
Presentation Completeness	9. Introduction Section	5	Very Good
	10. Content Section	5	Very Good
	11. Closing Section	5	Very Good
	Total	54	Very Good

Table 5. Assessment of language aspect by subject matter expert

Assessment Indicator	Assessment Items	Expert Score	Interpretation
A. Clarity	1. Accuracy of sentence structure	5	Very Good
	2. Sentence effectiveness	5	Very Good
	3. Terminology consistency	5	Very Good
B. Communicative	4. Message readability	4	Good
	5. Accuracy of language rule usage	4	Good
C. Dialogical and Interactive	6. Ability to motivate messages and information	5	Very Good
	7. Ability to encourage critical thinking	5	Very Good
D. Suitability with Student Development Level	8. Suitability with students' intellectual development	4	Good
	9. Suitability with students' emotional development	5	Very Good
E. Coherence and Logical Flow	10. Coherence and logical flow within learning activities	5	Very Good
	11. Coherence and logical flow between paragraphs	4	Good
F. Use of Terms, Symbols, or Icons	12. Consistency in term usage	5	Very Good
	13. Consistency in symbol and icon usage	5	Very Good
	Total	**60**	**Very Good**

Table 6. Results of subject matter expert assessment

Assessment Aspect	Maximum Score	Expert Score	Percentage (%)	Interpretation
Content Feasibility	100	90	90	Very Good
Presentation	55	54	98.18	Very Good
Language	65	60	92.3	Very Good
Final Result	220	204	92.72	Very Good

The subject matter expert's assessment of the language aspect in the development of this learning media received a score of 60. When converted into a percentage, it results in a value of 92.30%, with an interpretation of "very good," as shown by the data in Table 5 The final score from the subject matter expert's assessment will determine whether the material in the developed

learning media meets the core competencies, basic competencies, and other essential competencies.

According to the recorded data from each aspect in Table 6, the subject matter expert has evaluated the development of learning media on the introduction of Air Conditioning System components with a percentage of 92.72%, interpreted as "very good." Based on these findings, it can be concluded that the learning media on the introduction of Air Conditioning System components aligns with the scope of Core Competencies, Basic Competencies, Indicators, and the applied content.

3. Media expert validation

Before the media expert fills out the provided questionnaire, they first test the application along with the learning module, which contains material on the introduction to Air Conditioning Technology system. The module and application are consulted with the media expert until they are deemed suitable for use. After testing the application and module, the media expert can then answer the questions in the prepared questionnaire. The feasibility data of the learning media is collected using the following data:

Table 7. Assessment of application display quality aspects of MARVEL by media experts

No	Assessment Indicator	Expert Score	Inter pretation
1	Icons/buttons that facilitate user interaction with the Android-based mobile media	5	Very Good
2	Initial screen presentation of the Android-based mobile media that facilitates activity selection	5	Very Good
3	Clarity of menu hierarchy and electronic component learning materials in the Android-based mobile media	4	Good
4	Page layout arrangement	5	Very Good
5	Appropriateness of text color usage and font type in the Android-based mobile media	4	Good
6	Appropriateness of image proportions presented in the Android-based mobile media	5	Very Good
7	Loading process performance in the Android-based mobile media (hack and crash)	4	Good
	Total Score	**32**	**Very Good**

The data presented in Table 7, shows that media experts' assessment of the display quality aspects of the MARVEL software, as an educational resource for introducing components of the Air Conditioning Technology system, received a score of 32. When converted into a percentage, it achieves a value of 91.42% with an interpretation of "excellent."

Table 8. Assessment of software engineering aspects of the application

No	Assessment Indicator	Expert Score	Interpretation
1	Ease and simplicity in operating the Android-based mobile media	4	Good
2	Ease of content search (materials or information)	4	Good
Total Score		8	Good

According to the data available in Table 8, media experts' assessment of the software engineering elements in the MARVEL application as a learning medium for introducing components of the Air Conditioning Technology system received a score of 8. When converted into a percentage, it shows a score of 80% with a "good" interpretation.

Table 9. Assessment of the feasibility aspects of the MARVEL application by media experts

No	Assessment Indicator	Expert Score	Interpretation
1	Android-based mobile media can be used anytime and anywhere by students	5	Very Good
2	Presentation of Air Conditioning Technology system introduction materials enables students to learn independently	5	Very Good
Total Score		**10**	**Very Good**

The data shown in Table 9, indicates that media experts' assessment of the feasibility elements the Air Conditioning Technology system related to the use of the MARVEL application as a learning medium received a score of 10. When converted into a percentage, it achieves a value of 100% with an interpretation of "excellent."

Table 10. Assessment of the interface aspects of the MARVEL application by media experts

No	Assessment Indicator	Expert Score	Interpretation
1	The interface of the Android-based mobile media has a good layout	5	Very Good
2	The design of the Android-based mobile media display matches the user level	5	Very Good
3	Accuracy of color selection, color balance, font type, and font size in the Android-based mobile media	4	Good
4	Suitability of image format and resolution displayed in the Android-based mobile media	5	Very Good
Total Score		**19**	**Very Good**

According to the data shown in Table 10, media experts' evaluation of the interface elements of the MARVEL application as a learning medium for introducing components of the Air Conditioning Technology system received a score of 19. When converted into a percentage, it shows a value of 95% with an interpretation of "excellent."

Table 11. Assessment of the reusability aspects of the MARVEL application by media experts

No	Assessment Indicator	Expert Score	Interpretation
1	Some or all learning programs in Android-based mobile media can be reused to develop other learning media	4	Good
Total Score		**4**	**Good**

Table 12. Assessment of the maintainability aspects of the MARVEL application

No	Assessment Indicator	Expert Score	Interpretation
1	The Android-based mobile media application is easy to install or uninstall from the mobile system	4	Good
2	The master application of Android-based mobile media is easy to transfer from one mobile phone to another	4	Good
Total Score		**8**	**Good**

According to the data in Table 11, media experts' evaluation of the reusability elements of the MARVEL application as a learning medium for introducing the Air Conditioning Technology system received a score of 4. When converted into a percentage, it shows a value of 80% with an interpretation of "good."

As a learning medium for introducing components of Air Conditioning Technology, the MARVEL application received a score of 4. When converted into a percentage, it achieves a value of 80%, which is categorized as "good," according to the data in Table 12.

Table 13. Assessment of the compatibility aspects of the MARVEL application by media experts.

No	Assessment Indicator	Expert Score	Interpretation
1	The Android-based mobile media application can run on all Android versions	5	Very Good
2	The Android-based mobile media application can run on all screen resolutions	5	Very Good
Total Score		**10**	**Very Good**

According to the data shown in Table 13, media experts' assessment of the compatibility components of the MARVEL application as a learning medium focused on introducing Air Conditioning Technology received a score of 4. When converted into a percentage, it shows a value of 100% with an interpretation of "excellent." The total assessment from each element is then summed to determine the final score or percentage of the media evaluation conducted by media experts, ensuring the feasibility of the developed learning media based on the provided data.

Table 14. Media experts' assessment results for the MARVEL application

Assessment Aspect	Max Score	Expert Score	(%)	Inter pretation
Display Quality	35	32	91.42	Very Good
Software Engineering	10	8	80	Good
Implementation	10	10	100	Very Good
Interface	20	19	95	Very Good
Reusable	5	4	80	Good
Maintainable	10	8	80	Good
Compatibility	10	10	100	Very Good
Final Score	**100**	**91**	**91**	**Very Good**

Media experts also assessed the graphical feasibility aspect of the module with the following data: The development of learning media for introducing Air Conditioning Technology received a score of 4. When converted into a percentage, the tested MARVEL application achieved a score of 91%, with an interpretation of "excellent," according to the summary of each aspect in Table 14.

Discussion

The product developed in this research serves as a learning medium for introducing components of Air Conditioning Technology. The Mobile Augmented Reality for

Vocational Education Learning (MARVEL) application on Android smartphones contains this learning media. This application utilizes Augmented Reality (AR) technology, allowing users to view objects in three dimensions through images in the module [18].

The first step in developing this learning media is needs analysis. This process involves analyzing the curriculum to determine which products align with curriculum requirements. The curriculum analysis identifies themes that correspond to core competencies and basic competencies, ensuring that the learning materials presented in the media are relevant to those competencies.

The next stage is designing the product to be developed. This phase involves several activities, including determining the components for the three-dimensional media design (images, simulations, and content), conceptualizing the delivery and organization of materials, designing 3D models, creating markers, developing the AR system, designing the application menu, and creating the learning module. The outcome of this stage is an initial product design, which consists of the previously developed three-dimensional media concept. This design serves as a guideline for further product development [27].

Once the media is created, it will be reviewed with academic supervisors and tested by media and subject matter experts. The selection of media and subject matter experts for validation is conducted according to recommendations to ensure the appropriateness of the evaluation process [28]. This testing phase is crucial for validating the developed learning product. Researchers can identify deficiencies in the learning media and make improvements using the evaluation sheet. In the content validation process, subject matter experts assess the product based on various aspects, including content feasibility, presentation feasibility, and language evaluation.

The results indicate an average percentage of 92.72%, with an interpretation that the content presented in the learning media is excellent. Thus, this learning media is considered appropriate and aligns with the Core Competencies and Basic Competencies. The media evaluation examines various elements, such as display quality, software engineering, feasibility, interface, reusability, maintainability, and compatibility. These aspects are used to assess the MARVEL learning media application on Android smartphones.

Conclusion

After conducting research on the development of learning media through the mobile augmented reality for vocational education learning (marvel) application, several key findings were obtained regarding the feasibility of the learning media. The content validation conducted by subject matter experts resulted in a feasibility score of 92.72%, indicating that the material presented in the application is highly suitable and aligns with the required competencies.

Additionally, the construct validation by media experts yielded a score of 92.4%, reflecting the application's strong design, interface, and overall usability as a learning tool. Furthermore, teacher validation produced a score of 96.8%, suggesting that educators found the marvel application to be an effective and practical tool for vocational education.

These results demonstrate that the marvel application meets the necessary standards for educational media development, ensuring its feasibility, effectiveness, and alignment with the learning objectives in vocational education, particularly in air conditioning technology.

Acknowledgement

This research activity is funded by the Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Negeri Padang through the Applied Research Scheme, under Grant Number 899/UN35.13/LT/2021. The authors would like to express their sincere gratitude for this valuable support, which made the completion of this study possible.

References

1. J. R. Savery, T. M. Duffy, I. B. Wilson, E. Constructivist, L. Environments, and C. Studies, "Problem Based Learning: An instructional model and its constructivist framework," 1996.
2. I. W. Yusa, A. Yuniasti, R. Wulandari, B. Tamam, and I. Rosidi, "Development of Augmented Reality (AR) Learning Media to Increase Student Motivation and Learning Outcomes in Science," vol. 9, no. January 2018, pp. 127–145, 2023.
3. M. Ibáñez and C. Delgado-kloos, "Augmented reality for STEM learning: A systematic review," Comput. Educ., 2018, doi: 10.1016/j.compedu.2018.05.002.
4. E. Fitzgerald, R. Ferguson, A. Adams, and M. Gaved, "Augmented reality and mobile learning : the state of the art," no. October, 2015, doi: 10.4018/ijmbl.2013100103.
5. N. Hidayat, "Car Air Conditioner System Simulator Design for Student Practicum Perancangan Simulator Sistem Air Conditioner Mobil Sebagai Alat Praktikum Mahasiswa," pp. 151–160, 2023.
6. A. G. Kalay, "Perawatan Dan Perbaikan Sistem Air Conditioner Pada Mobil Daihatsu Taruna," 2015.
7. Buku Pedoman, Buku Pedoman Akademik FT Tahun 2018. 2018.
8. M. B. R. Wijaya, W. Wahyudi, W. Purwanto, K. Karnowo, D. T. Wahyudi, and A. Wiranto, "The Development of Learning Media for Automotive Electronics (Autotronics) Simulator Based on Measurement of Sensor Output Performance," pp. 1–6, 2021, doi: 10.4108/eai.27-8-2020.2305750.
9. A. Muslim, Karudin, M. Syafiq, H. Ruslan, and N. H. Kuo, Hsu-chan, "Augmented Reality-Enhanced 5-Step Project-Based Learning Framework for Advancing Technical Education Marco de Aprendizaje Basado en Proyectos de Cinco Pasos Potenciado con Realidad Aumentada para Avanzar en la Educación Técnica," 2024, doi: 10.56294/dm2024.647.
10. M. Demir, "Computers & Education," Comput. Educ., vol. 218, no. July 2022, p. 105091, 2024, doi: 10.1016/j.compedu.2024.105091.
11. U. N. Fatimah, "Pengembangan E-LKPD (Elektronik – Lembar Kerja Peserta Didik) Interaktif Menggunakan Google Slide With Pear Deck Dengan Raden Intan Lampung," Layanan Perpust. UINRIL Ref., pp. 1–58, 2021, [Online]. Available: http://repository.radenintan.ac.id/id/eprint/17097.
12. P. Dewi and A. Muhid, "Students' Attitudes towards Collaborative Learning through E-Learning During Covid-19: A Male and Female Students," English Teach. J. A J. English Lit. Lang. Educ., vol. 9, no. 1, p. 26, 2021, doi: 10.25273/etj.v9i1.9046.
13. M. N. Azmi, "Potensi Pemanfaatan Virtual Reality Sebagai Media Pembelajaran Di Era Digital," vol. 12, no. 1, 2024.
14. M. R. Cuhanazriansyah, Y. Cahyaningrum, D. Ayu, and N. Qolby, "Implementasi pembelajaran

teknologi informasi berbasis augmented reality di sekolah menengah kejuruan," vol. 8, no. 1, pp. 64–69, 2023.
15. R. T. Azuma, "A Survey of Augmented Reality," vol. 4, no. August, pp. 355–385, 1997.
16. D. W. Carruth, "Virtual Reality for Education and Workforce Training," Int. Conf. Emerg. eLearning Technol. Appl., 2017.
17. A. Kumar, A. Mantri, G. Singh, and D. P. Kaur, "Impact of AR-based collaborative learning approach on knowledge gain of engineering students in embedded system course," Educ. Inf. Technol., no. November, 2022, doi: 10.1007/s10639-021-10858-9.
18. Muslim, Ambiyar, Arwizet Karudin, Muhammad Syafiq Hazwan Ruslan, Hsu-Chan Kuo, Nuzul Hidayat, Rido Putra, "Augmented Clutch Reality Mobile: Innovative Educational Media for Modern Engineering," vol. 102, no. 23, pp. 8603–8616, 2024.
19. S. Wulandari, "Media Pembelajaran Praktikum Jaringan Komputer Berbasis Augmented Reality dengan Metode Marker Based Tracking," Explor. J. Comput. Sci. Inf. Technol., vol. 5, no. 1, pp. 1–13, 2025.
20. V. Wiliyanti, S. N. Ayu, H. Noperi, and Y. Suryani, "A Systematic Literature Review: Pengaruh Media Pembelajaran Berbasis Augmented Reality Terhadap Pemahaman Konsep Dan Minat Belajar Peserta Didik," J. Sci. Educ., vol. 4, no. 2, pp. 953–964, 2024, doi: 10.52562/biochephy.v4i2.1359.
21. N. Anila, M. Adri, and U. N. Padang, "Pengenalan Kesenian Alat Musik Tradisional Sumatera Barat Dengan Augmented Reality Berbasis Mobile Device," vol. 6341, no. April, pp. 35–47, 2022.
22. Borg and Gall, "Educational research and development (R & D) is a process used to develop and validate educational production "," 1983.
23. S. Sugiyono, "Metode penelitian pendidikan (pendekatan kuantitatif, kualitatif dan r&d)," 2017.
24. Sugiyono, "metode penelitian kuantitatif kualitatif dan r&d," Bandung Alf. p. 143, 2011.
25. S. Arikunto, "Prosedur Penelitian Suatu Pendekatan Praktik," no. June, pp. 2011–2014, 2013.
26. R. Anggi, P. Sari, and D. Rosana, "Development of augmented reality integrated physics e-worksheet to improve students ' problem-solving skills," vol. 6, no. 2, pp. 150–161, 2022.
27. W. Wagino, H. Maksum, W. Purwanto, K. Krismadinata, S. Suhendar, and R. D. Koto, "Exploring the Full Potential of Collaborative Learning and E-Learning Environments in Universities : A Systematic Review," vol. 12, no. 3, pp. 1772–1785, 2023, doi: 10.18421/TEM123.
28. I. P. Dewi, L. Mursyidaa, T. Sriwahyuni, and N. Hidayat, "The Use of Augmented Reality in Sensor and Actuator Device Learning : Is It Effective in Enhancing Students ' Conceptual Understanding ?," Int. J. Inf. Educ. Technol., vol. 15, no. 4, 2025, doi: 10.18178/ijiet.2025.15.4.2292.
29. M. R. Braun, P. Walton, S. B. M. Beck, and W. London, "Illustrating the relationship between the coefficient of performance and the coefficient of system performance by means of an R404 supermarket refrigeration system," Int. J. Refrig., vol. 70, pp. 225–234, 2016, doi: 10.1016/j.ijrefrig.2015.10.020.
30. Z. Ma, H. Bao, and A. P. Roskilly, "Thermodynamic modelling and parameter determination of ejector for ejection refrigeration systems," Int. J. Refrig., vol. 75, pp. 117–128, 2017, doi: 10.1016/j.ijrefrig.2016.12.005.