Original Article

Karate in the digital age: Augmented reality for enhanced learning and performance

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Abstract
Background. The integration of Augmented Reality (AR) technology development became a trend in representing an application that can present virtual 3D objects in real-time compared to other technological applications. However, digital-based research was restricted in the field of karate. Objective. The aim of this research was to develop karate learning media concerning practicality, attractiveness, and accuracy aspects to enhance the learning outcomes of technical performance in the karate course for sports science students. Method. The research used the Research and Development method by using the Borg and Gall design, consisting of 10 stages: (1) Data Collection; (2) Planning; (3) Development; (4) Design Validation; (5) Design Revision; (6) Product Trial; (7) Product Revision; (8) Product Usage Trial; (9) Product Revision; (10) Mass Production. The participants included 7 experts, comprising 2 national karate coaches, 2 professors specializing in karate martial arts, 1 national karate athlete, and 2 media experts. Additionally, 45 sports science students participated in the product trial and signed an agreement form for this study. The instruments of this study included validation sheets for experts and questionnaires for product trial participants. The data analysis technique used SPSS version 25. Results. According to expert validation results, the development of AR-based karate learning media showed excellent results, which indicated an average validation result by experts of 90.6%. Students' responses to the use of this media in karate learning were very positive, with scores in small group trials of 85.7% and large group trials of 89.6%. Compared to conventional learning, virtual reality teaching was approximately 15% higher than traditional teaching. Conclusions. The findings in this study were expected to contribute to future karate learning. This was indicated by the high validation scores by experts and the positive and enthusiastic response of participants towards karate learning with the assistance of AR technology.
Keywords: - Augmented reality, learning media, karate

Introduction

In this digital era, challenges that were once prevalent have been effectively addressed, particularly in the realm of sports, such as the martial art of karate. Biomechanics stands out as a renowned field in the study of karate, focusing on the kinetic and kinematic analysis to refine movements and master specific techniques (Mailapalli et al., 2015; Rodríguez González et al., 2022; Schöffl & Schöffl, 2016; Vovkanych et al., 2022). Utilizing biomechanical analysis enhances the effectiveness and efficiency of movements in various techniques (Ciprandi et al., 2018; Falco et al., 2009; Grigoriou et al., 2018; Kibele, 2011). However, researchers continue to explore developments to facilitate training and instruction in karate (Antonaccio et al., 2022; Hadi & Ali, 2012; Moenig et al., 2023; Vertonghen et al., 2012). An illustrative example is the application of Augmented Reality (AR) technology in martial arts education. Previous research in pencak silat has successfully implemented AR, proving its efficacy in enhancing the quality of learning outcomes. Given the extensive practice required for conceptual understanding and skill development in karate (Franchini et al., 2014; Lassalvia et al., 2021; Vertonghen et al., 2012, 2014), supportive media is crucial to accelerate the comprehension of motion concepts during karate instruction (Kostrzewa-Nowak et al., 2019; Marlina et al., 2023; Vertonghen et al., 2012; Vovkanych et al., 2022). As a companion or support tool in martial arts education, AR emerges as a solution with significant benefits and contributions, offering various advantages in the learning process.

Augmented reality is a technology that overlays virtual 3D objects in the real environment, providing an interactive and immersive experience. In the context of learning, augmented reality is utilized as a powerful tool to enhance the educational process, making it more engaging and effective. Augmented Reality (AR) is a blend of digital information, including 3D models, images, videos, and audio, seamlessly integrated into the real world and Android-based (Jones, 2013; Nelson et al., 2022). In line with this, improving the learning outcomes of

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martial arts techniques traditionally requires an extended period. However, limitations arise due to constraints in the availability of both time and space, not consistently provided by instructors or lecturers. Consequently, there is a need for a supporting medium to alleviate these challenges, and one suitable option is learning media utilizing AR technology.

Media refers to the materials and tools used to facilitate learning. It encompasses a wide range of resources, including textbooks, audio-visual aids, and, in the modern era, digital platforms. The choice of learning media significantly influences the learning experience and outcomes. Augmented Reality (AR) is currently a trending instructional medium, though its application remains limited, particularly in the field of martial arts to enhance technical abilities. AR represents an evolution of previous learning methods involving books and computers, undergoing significant changes with the advent of handheld devices like smartphones (Pu & Yang, 2022). The primary goal of AR is to blend real-world situations with virtual conditions, allowing users to interact with both physical and digital objects (Kesim & Ozarslan, 2012). Consequently, there are no limitations, such as time or location. Aligned with this, learning facilitated by mobile devices has gained immense popularity, aiding educators and learners, including students and athletes, in enhancing performance. AR serves as a motivating factor for users to engage in learning anytime and anywhere (Dengel et al., 2022; Haris et al., 2023; Jeong et al., 2009).

Augmented Reality (AR) applications offer a focused platform for various techniques within a structured program (Soltani & Morice, 2020), and can be selected as training modules to enhance performance. However, a current challenge arises during athlete or student practice sessions, where they need to remember the coach's instructions in detail. Forgetting the taught movements makes it difficult to improve technical skills. Traditionally, print materials have been used as a control in learning. Despite, extensive research on various learning media do not align with standardized curricula and objectives (Bidarra & Rusman, 2017; Nelson et al., 2022). This study aimed to develop AR-based digital technology to overcome these limitations. The advantage lies in the flexibility of learning—anytime, anywhere, and with anyone, promoting efficient and effective learning. Moreover, students can explore karate techniques extensively through AR, thereby enhancing motivation. The AR application can be developed using Unity 3D and Blender software. AR can be seen as a blend of real-world and seamlessly integrated virtual elements.

In this context, AR undoubtedly provides advantages in human-computer interaction through appealing objects visually that resemble real-world items, presented in three dimensions (3D) for enhanced clarity and real-time visualization. Engaging learning media, such as dynamic displays or animations, make it easier for learners to remember and absorb content. AR technology imparts abstract concepts, catering to learners' continuous developmental stages and preferences (Cheng & Tsai, 2013; Hsu & Shih, 2016). In the educational realm, AR finds practical application by delivering easily understandable information and illustrating the content effectively. Karate, among numerous martial arts, has a rich history of development in Indonesia.

Karate, originating in Japan, has evolved into a globally recognized martial art. Beyond its physical aspects, it encompasses mental training, instilling values such as discipline, respect, and continual self-improvement. As a competitive sport, Karate is contested both nationally and internationally, featuring prominently in the curriculum of the Faculty of Sports Science (Chaabène et al., 2012; Lassalvia et al., 2021; Schwartz et al., 2015). In the realm of education, the instructional methods for karate techniques traditionally involve textbooks for theoretical knowledge and field practice for hands-on skill mastery. However, with the advancement of technology, educational approaches are transitioning from print and standalone computers to more integrated methods that combine printing technology with computer applications.

The current predicament in karate instructional materials revolves around the limited use of textbooks, PowerPoint presentations, and practical exercises. Self-learning without guidance from an instructor poses challenges, as it relies solely on textual materials without accompanying movement demonstrations and is constrained by limited practice time. While digital technology-based learning materials abound, many are produced without a comprehensive understanding of the curriculum and student needs. Given this scenario, the author contemplates a paradigm shift in content delivery by leveraging available resources. Harnessing the advancements in current technology, researchers aim to implement a Martial Art Augmented Reality (AR)-based digital learning medium designed to be as engaging as possible. Further development of Augmented Reality technology in both research and instructional materials is crucial for successful integration into the learning environment.

With its various benefits, AR technology is highly favored by students, particularly in martial arts education, where sequences of movements embody abstract concepts that require visual comprehension and repetitive practice (Hsu & Shih, 2016; Nelson et al., 2022). Therefore, the learning process can become more optimal. Given the complexity of these challenges, it is essential to develop AR-based learning media to support students in becoming more proficient in karate education. In the context of augmented reality and learning media, the integration of these technologies in karate education holds great potential. Augmented reality can provide a dynamic and interactive way for learners to visualize and practice karate techniques in a virtual setting. Media, enhanced by augmented reality, can offer a more immersive and engaging platform for students to grasp the intricacies of karate, ultimately improving their skills and understanding of this martial art.

The aim of this research was to create more engaging and efficient learning media using AR technology. The significance of this study lied in producing karate learning materials and offering solutions to instructors, addressing potential challenges that may arise during karate education.

Material & methods
Methods

The methodology employed in this research was the Research and Development approach with the Borg and Gall design, encompassing 10 stages (Borg, 2014): (1) Data Collection; (2) Planning; (3) Development; (4) Design Validation; (5) Design Revision; (6) Product Testing; (7) Product Revision; (8) Usage Testing; (9) Product Revision; (10) Mass Production. For a clearer understanding, refer to Figure 1.
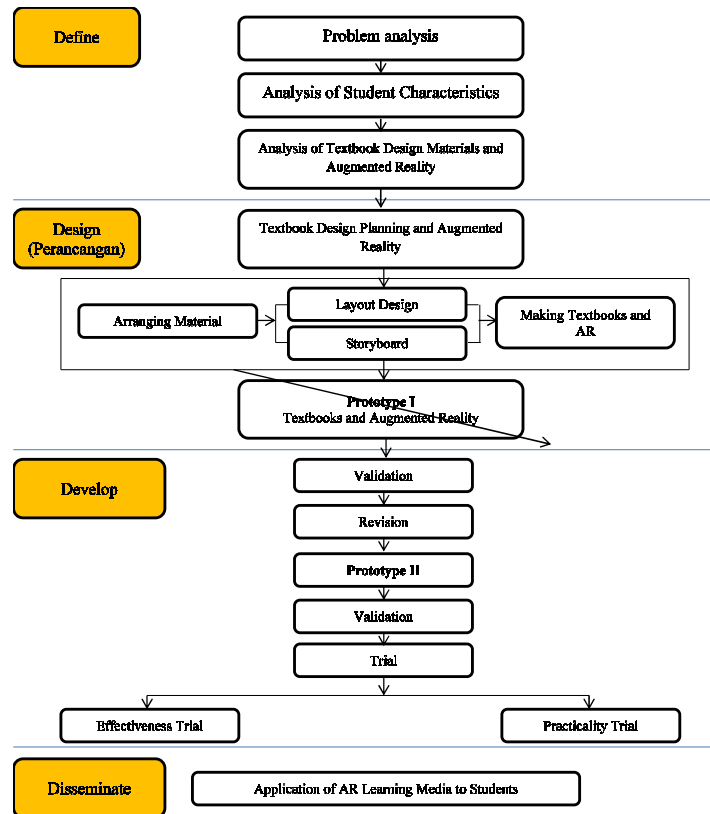

Figure 1. Research flow diagram

In addition, to obtain expert opinions for assessment, a Likert scale with values ranging from 1 to 5 was employed. For a clearer presentation, refer to Table 1.

Table 1. Expert Assessment Norms Per Item on the Expert Assessment Questionnaire.

No.	Category	Score
1	Very worth	5
2	Worthy	4
3	Decent worth it	3
4	Not worth it	2
5	Not Feasible	1

Therefore, after obtaining the percentage value, it were categorized into qualitative elements to assess the feasibility of the developed product.

Participants

Participants in this study included 7 experts, comprising 2 national karate coaches, 2 professors specializing in martial arts, 1 national karate athlete, and 2 media experts. Meanwhile, 45 sports science students, consisting of 15 individuals (males n=10 and females n=5) for the small-scale test and 30 individuals (males n=20 and females n=10) for the large-scale test, participated as subjects who had signed a consent form for product testing in this research.

Research Instrument

The instruments employed in this study were questionnaires. The first questionnaire aimed to assess the validation and feasibility of the product used for learning. The second questionnaire aimed to gauge the students' responses to the developed product.

Statistical Analysis

The data were analyzed using SPSS 25, and Microsoft Excel was utilized to analyze the data by calculating the percentage of improvement.

Procedures of research

The procedure included: (1) Data Collection. In this phase, the potential problem was identified, namely the lack of development in instructional media used by instructors in karate lectures, and no found; (2) Planning. The prototype stage began with a need's assessment, followed by the development of a Karate learning media prototype using AR technology based on Android. In this stage, a flowchart, storyboard, AR application design based on Android, Markers, and Marker Books were created. The flowchart for developing the Karate learning media prototype using AR technology was shown in Figure 1; (3) Development. In the prototype creation stage, Markers and Marker Books containing Karate Learning sub-concept materials were developed by the course syllabus, scannable using the developed AR application along with its markers. The created markers were compiled in the Marker Book, which, in addition to containing markers scannable using the AR media application, also included materials and exercise questions for students to study and demonstrate Karate techniques; (4) Design Validation. The next step after creating the product design was to seek validation from experts, including Karate material experts, media experts, and technology experts; (5) Product Trial. Small and large-scale product trials in this study were conducted with students from FIK UNP; (6) Design Revision. The next step after conducting large-scale trials was to improve certain aspects considered insufficient by experts. Adjustments are made to ensure that the resulting product is truly suitable for widespread use; (7) Product Revision. The next step after conducting large-scale trials was to improve certain aspects considered insufficient by experts. Adjustments are made to ensure that the resulting product was truly suitable for widespread use; (8) User Trial. Small and large-scale product trials in this study were conducted with students from FIK UNP; (9) Product Revision. The next step after conducting large-scale trials was to improve certain aspects considered insufficient by experts. Adjustments were made to ensure that the resulting product is truly suitable for widespread use. (10) Mass Production. The products resulting from the development of the pencak silat learning media were in the form of a CD with multimedia technology-based desktop applications. It is hoped that the created product can assist instructors in obtaining instructional media for the Karate course. The overall research procedure can be illustrated in the following **Figure 1.**
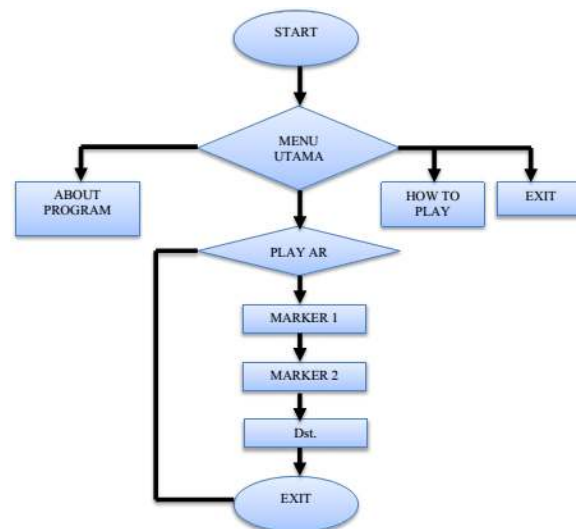

Figure 1. Product Design.

Statistical analysis

The data were divided into two parts: qualitative data, which consisted of suggestions and criticisms from instructors and students in the Karate lectures at FIK UNP, and quantitative data from the provided questionnaires. All data were analyzed using SPSS version 25 to calculate the overall results.

Research design

Materials and methods were explained in detail, informative and obligatory citations were required, e.g. on research methods used/data collection techniques/formulas etc. Insert the validity and reliability value of the instrument were used for the measurement. Describe the data analysis technique was used. Insert the research

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license/ethical approval number if required. Parametric or non-parametric statistical analysis should be explained by standard statistical analysis.

Results

This research was conducted from March to September 2023 at the Faculty of Sports Science, Universitas Negeri Padang. The developed product aligned with the research stages, and the design of this study can be seen in the **Figure 2-8** as the output of this research.
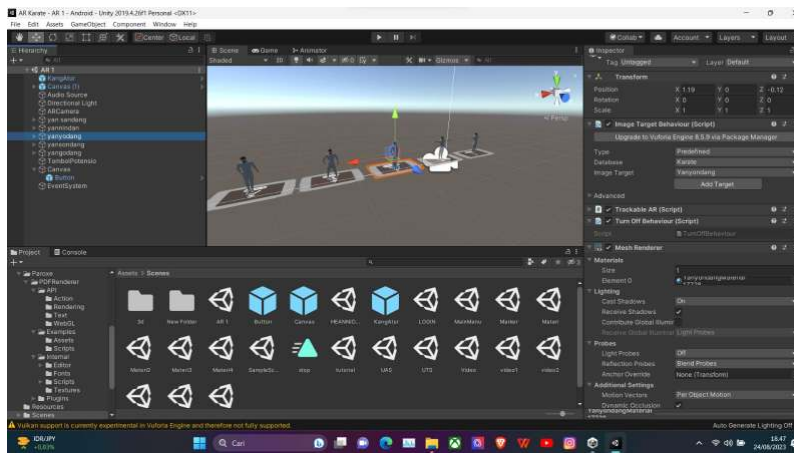

Figure 2. Design Display of AR Karate Learning.

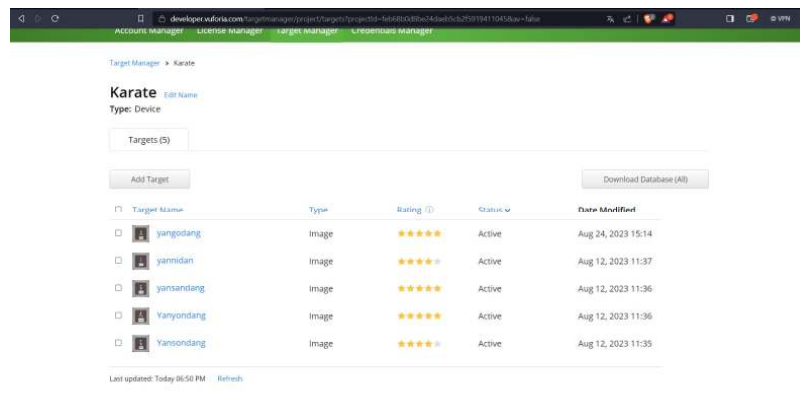
Figure 3. Menu Options for Demonstrated Movements.

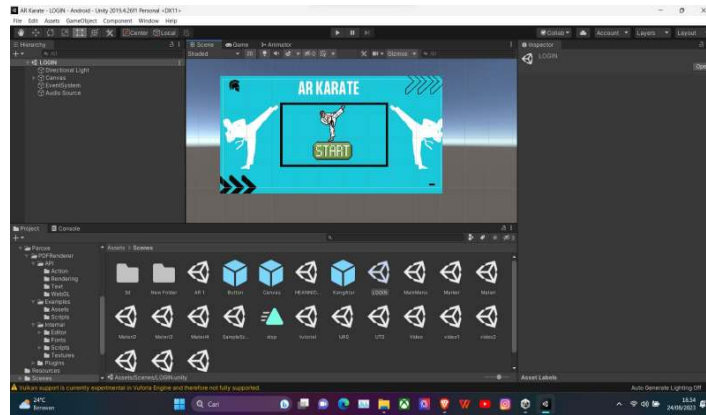**Figure 4.** Consumer/User Assessment of the AR Karate Application.

Figure 5. Showing the application log menu.

Figure 6. Detailed virtual position display.
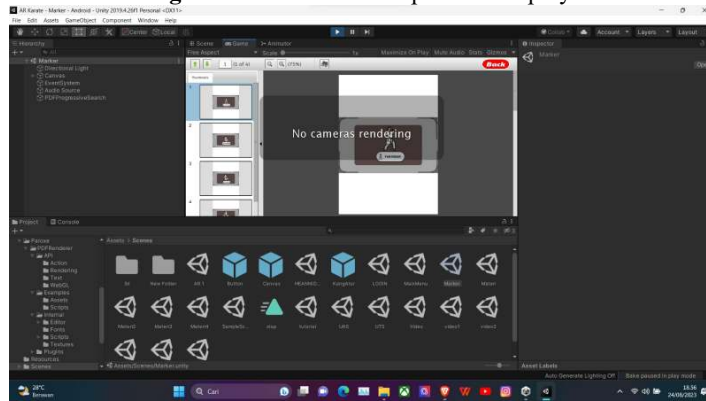

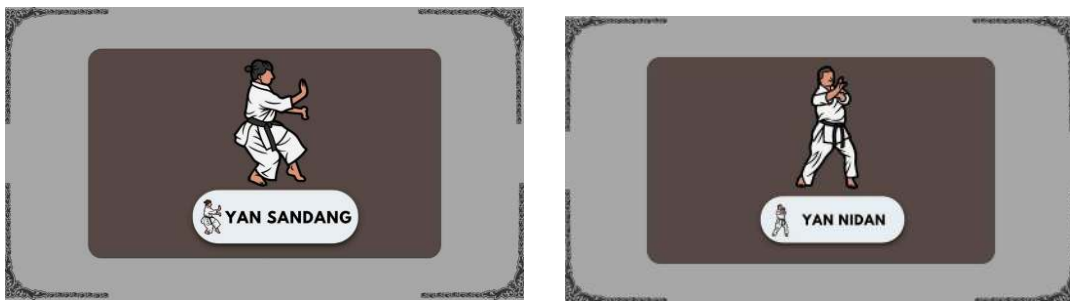**Figure 7.** AR Karate Application Marker Display.

Figure 8. Example Illustration of Techniques in Karate Available in AR Karate.

Expert Evaluation

        One of the data acquisition methods in this research was obtaining feedback on the developed product, which was an AR-based basic pencak silat learning media application, from technology experts in instructional

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design through a validation sheet questionnaire. The aspects validated included the quality of the display and presentation, along with suggestions and conclusions. The assessment process by instructional design technology experts was conducted in two stages. Based on the data analysis, the media expert evaluation of the augmented reality-based karate learning media development product resulted in an average score of 92%, indicating suitability (with individual scores of 90% and 93%). Therefore, it implied that the AR karate learning application was acceptable without modification and can be used. For a clearer understanding, refer to **Table 2**. for the expert assessment results.

Table 2. Evaluation Results by Experts on the AR Karate Product.

Variable	Max	Score	Percentage	Information
Quality of media content	**30**	**27**	**90%**	**Excellent**
Media appearance	**45**	**42**	**93%**	**Excellent**
Average score			**92%**	**Excellent**

Therefore, it was known that Augmented Reality (AR) learning media falls into the "Very Good" category in terms of media quality and media display. The next step was to calculate the total average by adding the average scores of all validators and dividing by the number of validators. The result that used the formula Percentage = F: N (F = Total Number of Subjects and N = Number of subjects) was the average score of each validator: (89.3% + 90.5% + 92%) : 3 = 90.6%.

Based on the validation results by subject matter experts, media experts, and technology experts on the Augmented Reality-based karate learning media product at the Faculty of Sports Sciences, Universitas Negeri Padang, was 90.6%, it said valid category without the need for improvement.

Trials of small group

The trial was intended to obtain direct feedback from users about the quality of the development being undertaken. Before the product trial, it was consulted with subject matter experts and media experts. After receiving feedback, it needed to revise or not revise the product based on the suggestions received. The next step was the trial, which was expected to identify weaknesses, deficiencies, errors, and suggestions for improvement so that the resulting product can be revised to produce a valid and usable product.

In the implementation of the small group trial, 15 students from the Sports Science program were randomly but representatively selected (students taking the Karate course in the same semester). The process of the small group trial was by providing a product in the form of Augmented Reality-based karate learning media development. Subsequently, to assess the developed product, the researcher provided an assessment questionnaire to the students. The results of the small group trial development evaluation showed as **Table 3**:

Table 3. The data from the product assessment in the small group trial was as follows:

No Respondent	Results of Assessment
Respondent 1	94.87%
Responden 2	87.96%
Responden 3	89,3%
Responden 4	86,7%
Responden 5	94%
Responden 6	82,7%
Responden 7	90,6%
Responden 8	95%
Responden 9	92%
Responden 10	69,3%
Responden 11	68%
Responden 12	77,3%
Responden 13	81,3%
Responden 14	90,7%
Responden 15	87 %
Score Total	1.286,73
Mean Total	85,7
Percentage	85,7%

Based on the results of the small-scale product testing for the AR-based karate learning media at the Faculty of Sports Sciences, Universitas Negeri Padang, it categorized "Excellent" (85.7%) that no revision was needed. In the small group trial, respondents gave positive feedback on this product, namely the development of AR-based karate learning media at the Faculty of Sports Sciences, Universitas Negeri Padang, wass already good and hopefully its quality can be further improved to meet the evolving needs and technology.

Large-scale usage trial

The trial of the product on a large group was the final trial, involving 30 students majoring in Health

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and Recreation at the Faculty of Sports Science, Universitas Negeri Padang. The process of conducting the large-scale product trial involved providing the developed augmented reality-based karate learning media product to the participants. The researcher distributed assessment sheets to the respondents. Based on the results of the large-scale trial evaluation, the findings were as Table 4.

Table 4. The data from the product assessment in the trial of the large group.

No Respondent	Results of Assessment
Respondent 1	88%
Respondent 2	98,6%
Respondent 3	94,6%
Respondent 4	89,3%
Respondent 5	92%
Respondent 6	90,6%
Respondent 7	98,6%
Respondent 8	88%
Respondent 9	94%
Respondent 10	92%
Respondent 11	93,3%
Respondent 12	89,3%
Respondent 13	95%
Respondent 14	94%
Respondent 15	92%
Respondent 16	97,3%
Respondent 17	94,6%
Respondent 18	86,6%
Respondent 19	73,3%
Respondent 20	93%
Respondent 21	96%
Respondent 22	95%
Respondent 23	88%
Respondent 24	80%
Respondent 25	74,7%
Respondent 26	92%
Respondent 27	72%
Respondent 28	93,3%
Respondent 29	84%
Respondent 30	76%
Score Total	2.689,1
Mean Total	89,6
Percentage	89,6%

Based on the results of the large-scale trial of the Augmented Reality-based karate learning media product at the Faculty of Sports Sciences, Universitas Negeri Padang, it falls into the "Excellent" category (89.6%) with the note that no revision is needed. In the large-scale product trial, there were no suggestions or comments for product revisions. It indicated that the development of Augmented Reality-based karate learning media at the Faculty of Sports Sciences, Universitas Negeri Padang, was deemed suitable for use by beginners, students, and lecturers as one of the learning resources or karate learning media.

Discussion

The previous studies conducted by coaches/lecturers were conventionally carried out through face-to-face learning (Fachrezzy et al., 2020; Ilham & Dimyati, 2021; Izzo et al., 2023; Mario et al., 2022; Nugroho et al., 2021). One limitation identified in the field is that coaches or lecturers do not have full-time availability to teach karate techniques, necessitating the use of learning media as a complement to the teaching process. The primary focus of this developmental research was to transform conventional learning, previously conducted face-to-face with an instructor or coach, into a form of learning that can be utilized not only in direct interaction with the instructor but also through virtual media that serves the same function as the coach.

The developed learning media takes the form of an AR technology-based application program for teaching Karate martial arts to sports science students, aiming to achieve efficient and effective learning. The main aspects emphasized in AR-enabled learning include spatial ability, practical skills, conceptual understanding, and inquiry-based activities (Cheng & Tsai, 2013; Grodotzki et al., 2023; Hsu & Shih, 2016). This learning media product is designed to enable individuals, especially beginners, to learn and practice independently using the provided learning materials, particularly focusing on the basic principles of Karate as outlined in the guidebook and the curriculum. Thus, the developed product of AR-based basic karate technique learning media can serve as a learning source and an alternative medium to introduce fundamental self-defense

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techniques of karate to beginners, especially students in their academic studies. It is expected that the use of Augmented Reality-based media will serve as an independent learning source, encouraging students to actively engage with the material, enhancing their autonomy, and improving their learning outcomes.

This research successfully discovered Augmented Reality (AR) as a tool to enhance motivation and has engaging features for students. The findings of this study support previous research stating that AR is a crucial learning medium, enabling learners to observe, analyze, and connect reality and virtual elements during training sessions, proving beneficial in various situations and locations. One limitation identified in the study is the absence of experimentation, which will be addressed in future research. The sample size for subsequent studies will be increased to avoid biases in the results. It's important to note that AR is closely related to reality; it aids in conceptual understanding, but the level of experience must be enhanced to achieve high-quality learning outcomes. (Soltani & Morice, 2020).

Based on the content validity score obtained, the learning media developed in this study, was perceived by student responses, which resulted in increased enthusiasm for learning. This indicated that students were more engaged in the learning process when using augmented reality media, leading to efficient and effective learning.

Conclusions

In conclusion, the research focused on the development and integration of Augmented Reality (AR) technology into karate learning media with the objective of enhancing practicality, attractiveness, and accuracy in technical performance outcomes for sports science students. The study's findings contribute valuable insights for future developments in the field of karate education, emphasizing the potential benefits of incorporating advanced technologies, such as AR, to enhance learning outcomes and student engagement.

The AR Karate learning media proved to exhibit a commendable content validity score, affirming its suitability and functional efficacy. The overwhelmingly positive attitude of karate course participants, predominantly students, towards AR-assisted karate instruction further substantiated its success. The realization of enhancing students' enthusiasm for learning karate attested to the efficacy of this innovative approach.

The study engaged a diverse group of participants, including national karate coaches, professors specializing in karate martial arts, a national karate athlete, media experts, and sports science students. Expert validation results revealed excellent outcomes, with an average validation score of 90.6%. The response from sports science students involved in product trials was notably positive, with small group trials yielding a score of 85.7% and large group trials scoring 89.6%. Additionally, the virtual reality teaching approach demonstrated approximately a 15% improvement in learning outcomes compared to traditional teaching methods.

As a forward-looking recommendation, the adoption of AR Karate technology as a versatile learning medium was advocated for both students and instructors. Its implementation can be done anytime, anywhere accessibility, ensuring heightened learning efficiency and effectiveness. In the realm of educational technology, the AR Karate media revealed as a valuable asset for optimizing the karate learning experience.

Nevertheless, the development of AR-based karate learning media has significant potential to positively impact karate education. The high validation scores from experts and the enthusiastic response from participants indicate that the integration of AR technology in karate learning can be an effective and engaging approach.

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