Development of an AR-based flipbook as an innovative learning resource

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Abstract: In the 21st century, globalization and digital transformation have significantly altered human life patterns. Digital technology has become central to nearly all aspects of life, including the education sector in Indonesia. Technological skills and readiness to meet the demands of the job market have become increasingly critical. Vocational education, such as vocational high schools, aims to equip students with the competencies necessary to compete in the global market. However, challenges in enhancing the quality and relevance of education remain a significant issue. In fact, according to Indonesia's Central Statistics Agency (BPS), the unemployment rate for vocational high school graduates reached 9.6% in 2023, the highest among all education levels, underscoring the urgent need for innovative approaches in vocational learning. One proposed solution is the development of flipbook-based learning media integrated with Augmented Reality (AR) to enhance student engagement and skills in the digital era. This study employed ADDIE (Analyse, Design, Development, Implementation, Evaluation). The results indicate that the VOCAR-FLIP model is significantly effective in improving students' learning outcomes, particularly in terms of academic achievement and conceptual understanding. These findings are expected to contribute meaningfully to the advancement of more innovative and effective educational technologies for future learning.

Keywords: ADDIE; augmented reality; flipbook; environmental occupational safety and health

1. Introduction

The 21st century is marked by an era of globalization that has brought significant changes to life patterns compared to previous centuries. These changes align with the era of digital transformation, where digital technology has become central to nearly all aspects of life (Plekhanov et al., 2023; Faidlatul Habibah & Irwansyah, 2021). In this era, the ability to adapt rapidly and possess competitive skills is crucial for seizing job opportunities. Information technology has become the foundational pillar of human life, including the education sector in Indonesia. Advanced skills, particularly those related to technology, are essential (Rahayu, Meirawan, et al., 2024; Ciarli et al., 2021). In the workforce, prospective employees must demonstrate comprehensive readiness to meet the dynamic demands of the market and technological advancements (Li, 2024; Rahayu, Ghinaya, et al., 2024). Consequently, individuals must prepare themselves thoroughly to navigate these changes. Furthermore, as noted by (Xinming, 2023; Alenezi et al., 2023) educational institutions, particularly vocational education, must ensure that their graduates are equipped to face these challenges by cultivating relevant skills necessary for competition in the digital era.

Vocational education, particularly as implemented in Vocational Schools, serves as a specialized pathway aimed at preparing students for direct entry into the workforce (Grundall & Mack, 2023). Its primary purpose is to equip learners with the skills and knowledge required to compete effectively in the global job market, whether in the industrial sector or other professional environments, and to develop expertise in their chosen vocational fields (Herbert et al., 2020). Despite its potential, vocational schools face significant challenges in fostering student development, particularly in cultivating abilities that not only improve their personal and professional quality of life but also enhance their capacity to innovate and establish independent ventures. These challenges align with the strategic goals of vocational schools, which emphasize three primary career trajectories: securing employment, pursuing further education, and embarking on entrepreneurial endeavour's (Alfaen & Ismail, 2024).

On the other hand, there remains a pressing need to enhance the role of vocational high schools in producing skilled middle-level workers. Low productivity is frequently the result of trade vocational school graduates' insufficient competencies (Song & Xu, 2024), which subsequently contributes to high unemployment rates among those entering the labour market for the first time. According to data from Indonesia's Central Statistics Agency (BPS), as of February 2023, the unemployment rate for vocational school graduates reached 9.6%, the highest among all educational levels. This highlights the urgent need for further efforts to improve the quality and relevance of vocational education, ensuring that graduates are better prepared and more competitive in the workforce (Kovalchuk et al., 2022; Indrawati & Kuncoro, 2021).

Currently, industries and the workforce demand professionals who are competent and capable of competing to produce high-quality products. Therefore, the selection process for prospective employees must be conducted carefully to ensure alignment between the required skills and the candidates' abilities. The need for skilled and qualified human resources continues to grow, both now and in the future (Piwowar-Sulej, 2021). However, several challenges, such as low learning motivation among vocational school students, often lead to concentration issues, which hinder the optimal mastery of the skills expected from graduates (Nupiah et al., 2022).

One factor contributing to the low interest and academic achievement among vocational school graduates is the use of less-than-ideal and non-interactive learning media (Xu et al., 2024). Commonly employed methods, such as PowerPoint presentations and modules, often fail to effectively support an optimal learning process. Several previous studies have attempted to address this challenge by applying interactive media in vocational education. For instance, flipbook-based learning has been shown to improve student motivation and comprehension in vocational subjects (Bunari et al., 2024). Similarly, Augmented Reality (AR) applications have demonstrated potential in enhancing practical skills and student engagement (Goswami & Sharma, 2022). However, most of these studies tend to examine flipbooks and AR separately, with limited integration between the two approaches. This highlights a gap that the present study seeks to address by combining flipbook and AR technologies into a unified learning media, namely VOCAR-FLIP (Vocational Augmented Reality with Flipbook). This innovation is designed to cater to students' needs while addressing the challenges and demands of the digital transformation era. By leveraging advanced technology, this solution aims to enhance student engagement and skills amidst the rapid changes occurring in the educational landscape (Chiu, 2020; Okoye et al., 2021).

Flipbooks are simple interactive media that have been proven to effectively enhance student learning motivation (P. Oronce & O. Manalo, 2021). Meanwhile, Augmented Reality (AR) technology enables the integration of virtual objects into the real environment, creating a more engaging and immersive learning experience (Fitria, 2023; Sharma et al., 2022). This study aims to determine

the effectiveness of flipbooks equipped with AR technology as a learning tool in vocational schools. This approach is considered relevant given that vocational school students need to acquire practical skills that align with the demands of the digital era (Saari et al., 2021). The study also aims to evaluate the effectiveness of AR-integrated flipbook learning media in supporting the learning process in SMKs. The findings are expected to provide an innovative and interactive learning media alternative that can be effectively implemented in vocational education settings.

During the learning process, vocational schools encompass various fields of study within their foundational framework and curriculum structure. One of the subjects addressing Environmental Occupational Safety and Health (K3LH). K3LH is a shared responsibility among all individuals in a workplace, including students during their practical training (Gultom, 2021). Teachers deliver K3LH materials to equip students with the knowledge and skills needed to protect themselves while working, both in school and in professional environments, and to prevent workplace accidents. Consequently, K3LH holds a crucial role in vocational education, especially as students engage with hazardous materials, tools, and potentially dangerous work settings (Sanusi et al., 2023). Vocational students are required to study K3LH because understanding these concepts underscores the importance of maintaining workplace safety, health, and environmental sustainability (Bilgiç & Aytaç, 2024). This foundational knowledge is indispensable for vocational school students as they prepare to enter the workforce.

2. Methods

This research uses the RnD (Research and Development) method with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model as detailed in Figure 1. This model is used to develop and test the feasibility of learning media.

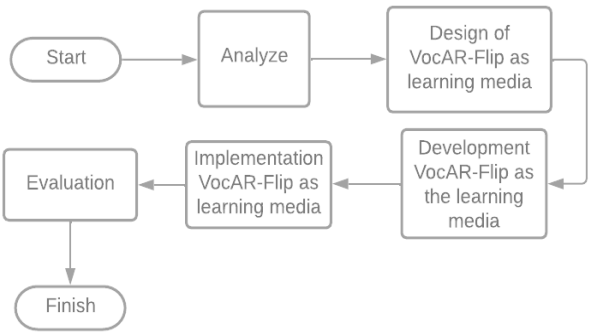

Figure 1. The ADDIE Model

In the development of learning media, the process begins with a preliminary study or needs analysis to identify key issues, including audience evaluation, instructional materials, media, and technology. Following this, the researchers move on to the Design phase, which involves creating flowcharts and storyboards (Rizal et al., 2022), followed by conceptualizing the learning media framework. This design is then implemented through the VOCAR-FLIP application. The next phase, Development, focuses on producing teaching modules and learning media in the form of an augmented reality-enhanced flipbook. The testing phase within this stage consists of several key steps: Alpha Testing, which includes validation by media and content experts (Rabiman et al., 2021), and Beta Testing, which involves user trials to assess product effectiveness (Ali & Yahaya, 2024). The validation of both media and content is conducted to determine the feasibility and suitability of the developed instructional media (Shakeel et al., 2023).

The research advanced to the Implementation stage, where the VOCAR-FLIPlearning media was applied. This phase involved deploying VOCAR-FLIP to a limited sample of 149 students. The final stage in the ADDIE model, Evaluation, aimed to collect feedback on the learning media's development, focusing on usability, visual appeal, and overall effectiveness in the learning process (Abuhassna et al., 2024). At this stage, students were given a questionnaire to assess their responses after using VOCAR-FLIP, providing insights into user experience and engagement with the augmented reality-enhanced flipbook (Nowicki et al., 2024; Norouzkhani et al., 2025). For data analysis, this study employed a descriptive quantitative approach. The feasibility of the application was evaluated using descriptive validation level analysis and user response assessment questionnaires to measure its effectiveness and appropriateness.

3. Results and discussion

3.1 Analysis condition

The analysis stage aims to identify and establish existing problems and the needs required by teachers and students in vocational schools. This analysis includes student characteristics and constraints in the learning process, which subsequently play a role in determining the knowledge and skills competencies that need to be learned, as well as in identifying student attitudes and learning objectives (Dick & Reiser, 1989). This process was carried out through observations and the distribution of questionnaires to teachers and students, with results indicating that they require interactive, innovative, and adaptive learning media to overcome current challenges in education.

Based on the analysis results, most students own and regularly use Android or iOS-based smartphones (99% and 96%). Most schools also have internet or Wi-Fi access (79%), although the technological facilities in schools that support learning are still around 84%. In the learning process, the use of technology is quite common, with 92% of teachers having utilized technology-based learning media and 95% having used it in teaching activities. In addition, 89% of teachers have introduced the use of smartphones as part of the learning process. However, only 15% of teachers consistently use varied learning media in each session.

Although most students feel that the teacher's explanation is well understood (85%), there are still 39% of students who experience difficulties in learning. On the other hand, most students (98%) consider the use of smartphones a necessity, and 94% believe that smartphones can make learning more enjoyable. From these findings, it can be concluded that although the use of technology in learning is quite high, there are still limitations in the variety of learning media used by teachers. Therefore, there is an urgent need to develop Android or iOS-based learning media, as supported by 96% of students who agree with this initiative.

3.2 Design of teaching module and application

The second stage focuses on identifying and designing the learning media to be utilized. This phase is conducted after completing the analysis process. During the Design phase, the product blueprint is developed, leading to the creation of the user interface. At this stage, the researcher selects and integrates essential media elements, including instructional materials, images, animations, audio, and videos from various sources. Figure 2 represents the storyboard used in the development of VOCAR-FLIP.

Figure 2. The storyboard of design VOCAR-FLIP

3.3 Development of application

In designing the VOCAR-FLIP application, the researchers utilized Unity software integrated with Vuforia to develop augmented reality (AR) features. This application is compatible with Android devices running version 7 or higher that support AR functionality. VOCAR-FLIP comprises two primary menus: Flipbook, which presents learning materials in the form of text, audio, and video, and Augmented Reality, which projects 3D objects into the real world. Additionally, the application includes an Information menu, Credits, and an Exit option, as illustrated in Figure 3.

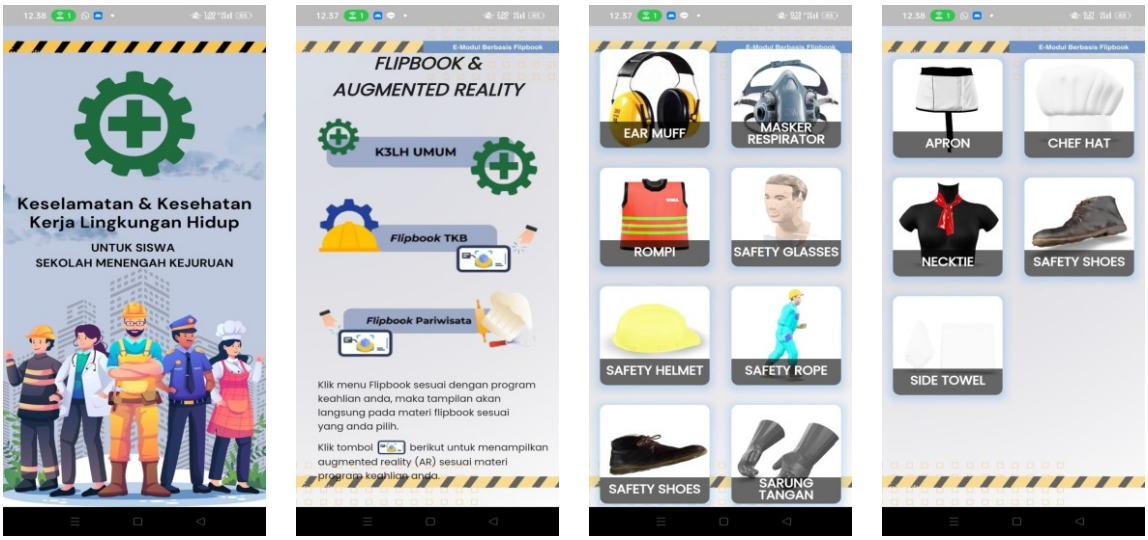

Figure 3. The menu of VOCAR-FLIP

In Figure 3, the development of a Flipbook with Augmented Reality is illustrated through the VOCAR-FLIP application, which was designed using Unity software and integrated with Vuforia to enhance the Augmented Reality (AR) experience. This application can be downloaded and installed via this link to provide users with a more immersive learning experience.

The development of AR applications can be accomplished using various technologies and platforms, one of the most prominent being Unity, a widely used game development engine. Unity offers numerous advanced features, including a robust editor, comprehensive APIs for programming, and strong support from a large developer community, all of which contribute to a seamless AR development process. As a cross-device platform, Unity enables the creation of AR applications compatible with multiple devices, such as tablets, smartphones, and head-mounted displays (HMDs) like HoloLens. Furthermore, Unity can be integrated with Vuforia, an advanced AR development platform that supports features such as 3D model rendering, animations, and real-time object and image recognition. The synergy between Unity and Vuforia significantly simplifies the creation of highly interactive and complex AR applications, making them more engaging and dynamic for users.

3.4 Implementation of using application

The Implementation stage involves executing a learning module or program in a real-world context, aiming to deliver instruction efficiently and effectively. The VOCAR-FLIP application for the K3LH subject was evaluated by students as respondents in the Beta test. A total of 149 vocational school students specializing in Building Construction Technology and Tourism Programs in West Java, who study Occupational Safety, Health, and Environment (K3LH) material, completed a questionnaire to assess the application's usability via Google Forms.

The questionnaire included four key indicators: usefulness, ease of use, ease of learning, and satisfaction. Each statement was rated on a 5-point Likert scale, ranging from strongly disagree to strongly agree. To ensure that the questionnaire items effectively measured the same latent variable, a reliability test using Cronbach's Alpha was conducted. A total of 149 students from Vocational School A, Vocational School B, and Vocational School C in the Building Construction Technology field, as well as Vocational School D and Vocational School E in the Tourism Vocational Program, participated in this implementation phase. Analysis of the questionnaire instrument demonstrated very high reliability, with a Cronbach's Alpha value of 0.943 for 26 statement items. The reliability level of the questionnaire is considered high if the Cronbach's Alpha value exceeds 0.8.

3.5 Evaluation

Evaluation is a process that takes place continuously and can be conducted at any time during the development and implementation of learning. This evaluation aims to assess the success of the development of the flipbook with Augmented Reality that has been developed. Revisions from expert validators are carried out as part of the evaluation that needs to be improved so that the developed VOCAR-FLIP is suitable for testing on specific qualifications. In this case, the review focused on the aspects of language, content, and media with several parameters as benchmarks. In addition, students' responses after using VOCAR-FLIP were also tested to determine the extent to which this Flipbook with Augmented Reality is considered effective as a learning medium in accordance with the initial goal, which is an interactive learning medium that can improve learning outcomes in vocational schools.

3.5.1 Expert panel validation test results

Once the development of the teaching media was completed, the research advanced to the Development phase. In an era of rapid technological advancement, students are expected to effectively and independently utilize digital learning media (Rahmatullah et al., 2022; Haleem et al., 2022). The language validation test results demonstrated strong validity, with the communicative aspect essential for user comprehension—achieving a score of 95% (Figure 4). This finding indicates that the instructional language used in VOCAR-FLIP is not only accurate but also user-friendly, thereby facilitating smoother learning interactions. Such clarity is particularly important, as previous studies have emphasized that accessible language in learning media enhances both usability and learning outcomes (Kholis, 2021; Abd. Syakur et al., 2020). The overall average score of 90% across all language aspects further confirms that the application meets excellent feasibility standards. This aligns with findings by Novaliendry et al. (2020) and Pensabe-Rodriguez et al. (2020), who highlight that clear instructional language increases students' confidence and willingness to engage with digital learning platforms.

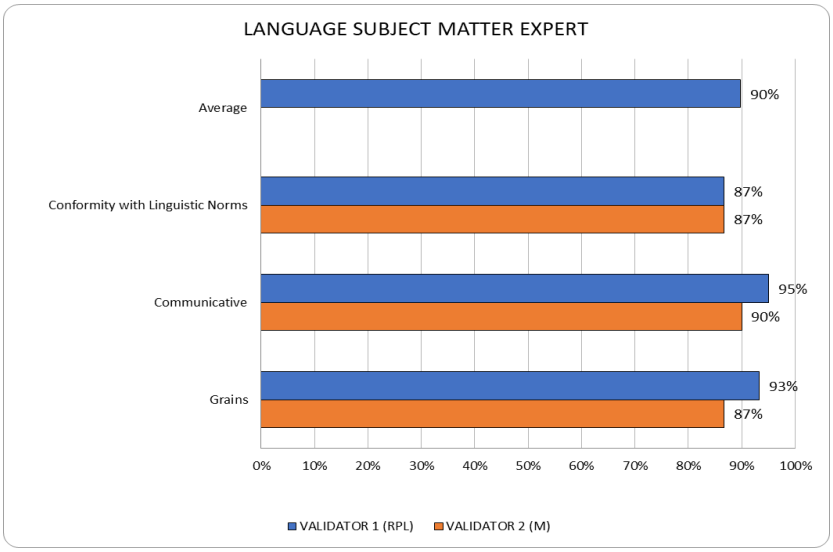

Figure 4. Expert panel result for language

According to Figure 5, the percentage of material in the characteristic aspect achieved the highest score in the independent concept suitability category, with a perfect score of 100%. This result suggests that the content presented in the application is not only accurate but also highly aligned with the principles of self-directed learning, enabling students to explore and construct knowledge more independently. Prior studies have emphasized that well-structured and relevant content strongly supports learner autonomy and improves long-term retention of knowledge (Harianja et al., 2021). In this regard, the overall validation results from subject matter experts, yielding an average of 97%, confirm that the developed material has reached an excellent level of feasibility. This finding is consistent with (Saputra et al., 2024), who argue that contextualized and structured learning resources significantly enhance vocational students' ability to transfer theoretical concepts into practical applications.

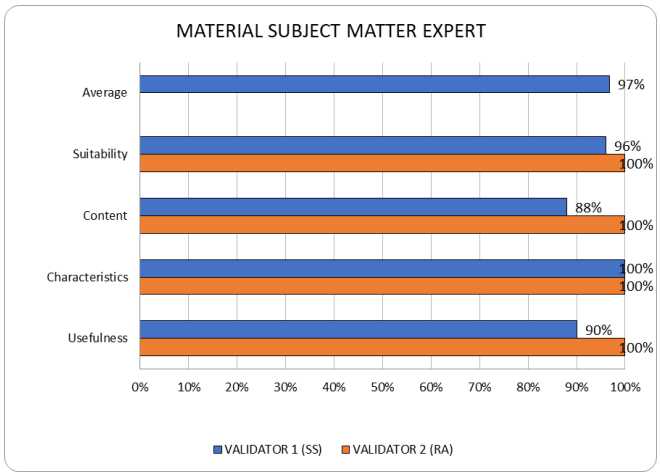

Figure 5. Expert panel result for material

As shown in Figure 6, the validation results of the media aspect in terms of attractiveness achieved the highest score of 100%. This indicates that the visual design and presentation of media are not only appealing but also effective in sustaining student attention during the learning process. Prior research highlights that engaging media design contributes to improved learner motivation and reduces cognitive load, making it easier for students to process complex information (Ediyani et al., 2020). The overall average score of 93% further demonstrates that the media aspect of VOCAR-FLIP has successfully met the criteria for feasibility. This is in line with (Sabitri et al., 2024), who found that interactive and visually appealing digital media significantly increase student participation and foster a more positive learning experience in vocational education.

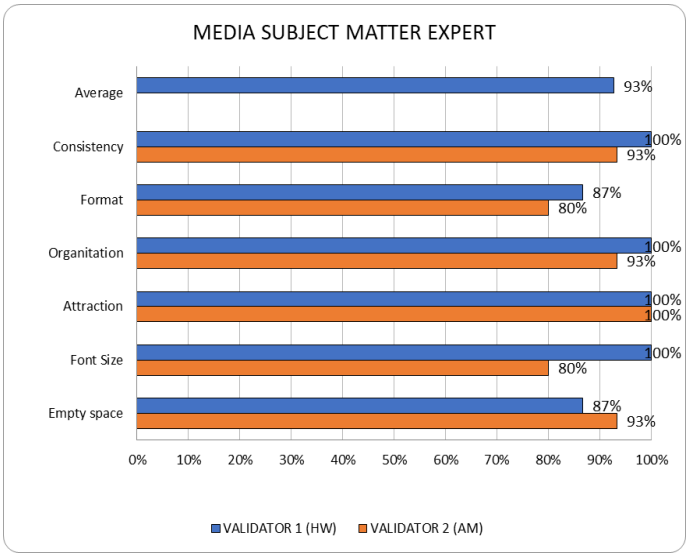

Figure 6. Expert panel result for media

3.5.2 Student response test results

This research included 149 respondents, as outlined in Table 1. The majority were female, comprising 85 participants (57.05% of the total), while the remaining 64 respondents (42.95%) were male. The participants were enrolled in three different study programs: Modelling Design and Building Information, Construction and Property Business, and Culinary. The Modelling Design and Building Information program had the largest representation, with 69 respondents.

Table 1. Respondents' characteristics

Dimension	Category	Frequency	Percentage (%)
Gender	Male	64	42.95
	Female	85	57.05
Expertise Program	Modelling Design and Building Information	69	46.31
	Construction and Property Business	56	37.58
	Culinary	24	16.11

It should be noted that the variation in gender and study programs within this research sample can provide broader insights into perspectives and responses to the topic being studied. Based on (Call et al., 2023), demographic data play an important role in understanding diversity and representation in analysing and interpreting research results. Table 1 presents the research results related to user responses after using the VOCAR-FLIP application.

Table 2. Respondents survey result

No	Description	1	2	3	4	5
		Strongly disagree	Disagree	Quite agree	Agree	Strongly agree
		Scale				
		SD	D	QA	A	SA
1.	Usefulness	0%	1%	11%	45%	43%
2.	Ease of Use	0%	3%	13%	42%	42%
3.	Ease of Learning	0%	2%	10%	43%	45%
4.	Satisfaction	0%	1%	12%	41%	46%

Based on the survey results in Table 2, the satisfaction criterion received the highest rating, with 46% of respondents giving a "strongly agree" response. This indicates that most students not only perceived VOCAR-FLIP as easy to use but also experienced a high level of satisfaction in terms of functionality and quality. Ease of learning, which also received consistently positive responses (45% strongly agree), further demonstrates that the application accelerates user adaptation to its features. This finding is consistent with Ferreira et al. (2020), who emphasized that user-friendly digital tools reduce the cognitive burden on learners, thereby allowing them to focus more on mastering the content rather than struggling with the medium itself. In vocational education contexts, such ease of adaptation is critical, as students are often required to integrate both theoretical knowledge and practical skills in a relatively short timeframe.

As shown in Table 2, respondents also recognized the attractiveness of the application, with 43% strongly agreeing that VOCAR-FLIP was able to capture and sustain their attention. This finding highlights the role of media design and interactivity in enhancing student motivation, which previous studies have identified as a key predictor of successful digital learning outcomes (Bitrián et al., 2021). Furthermore, 42% of respondents strongly agreed that the application was easy to use, suggesting that VOCAR-FLIP effectively lowers technical barriers to learning. Prior research indicates that reducing such barriers can directly improve learning efficiency and promote deeper engagement (Saleem et al., 2022). The high satisfaction scores, coupled with students' perception of usability, indicate that VOCAR-FLIP has the potential not only to support the learning process

but also to encourage repeated use, thereby fostering long-term user loyalty a characteristic seldom achieved by traditional media such as PowerPoint or printed modules.

Overall, the positive responses confirm that VOCAR-FLIP successfully meets user expectations in terms of functionality, usability, and attractiveness. The combination of high satisfaction, ease of learning, and appealing design suggests that the application can contribute significantly to student-centered learning approaches, which emphasize autonomy, motivation, and interactivity (Asiri et al., 2021). These findings also align with previous AR-based learning studies, which reported improved student engagement and conceptual understanding across diverse educational settings (Moser & Lewalter, 2024; Latif et al., 2024). However, some studies have noted potential challenges, such as increased cognitive load or technological barriers when AR tools are not well integrated into pedagogy (Alqahtani & Alnajdi, 2024). This indicates that while VOCAR-FLIP demonstrates strong effectiveness in vocational contexts, its success depends on thoughtful implementation and alignment with learning objectives. Beyond education, the results imply broader potential for AR-integrated learning media to be applied across different vocational domains and industrial training programs, thereby strengthening the practical relevance of digital learning tools in preparing students for the demands of Industry 4.0.

4. Conclusion

Based on the findings, the development of an Augmented Reality-based Flipbook for Occupational Safety, Health, and Environment (K3LH) materials—implemented using the ADDIE model—proved effective in enhancing learning through the integration of digital text with interactive 3D modeling. The validation results from language, material, and media experts confirmed the feasibility and effectiveness of the product, while user testing indicated that the application successfully increased learning engagement, satisfaction, and efficiency. Theoretically, this study strengthens the evidence that Augmented Reality-supported learning media can bridge the gap between abstract concepts and practical applications, particularly in vocational education where hands-on practice is crucial. It contributes to the growing body of literature that positions AR as a tool for improving motivation, self-directed learning, and contextualized understanding. Practically, the findings suggest that teachers can adopt VOCAR-FLIP to make K3LH instruction more interactive and relevant, thereby reducing students' boredom and increasing retention of safety concepts. For schools, implementing AR-based media can support the modernization of teaching resources in line with digital transformation demands. Policymakers may also consider integrating AR-supported learning media into vocational education curricula as part of broader strategies to improve graduate competence and workforce readiness. For future research, several directions can be pursued: (1) conducting longitudinal studies to evaluate the long-term impact of VOCAR-FLIP on students' practical skills and workplace readiness; (2) comparing its effectiveness with other immersive media such as Virtual Reality (VR) or Gamified Learning Systems; (3) exploring scalability and adaptability of this media across different vocational subjects beyond K3LH; and (4) assessing its effectiveness in diverse school environments, including rural or under-resourced settings, to examine equity and accessibility issues.

Author's declaration

Author contribution

Sri Rahayu: Conceptualization, methodology, supervision, writing-review & editing. **Danny Meirawan**: Methodology, validation, formal analysis, writing-review & editing. **M. Muktiarni**: Investigation, data curation, formal analysis, writing-review & editing. **Zahra Ghinaya**: Data

Curation, visualization, writing-original draft, writing-review & editing**. Zenita Sabitri**: Resources, investigation, project administration, writing-review & editing. **Aferro Ismail**: Validation, formal analysis, writing-review & editing.

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Competing interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Clearance

Permission to conduct the study was obtained from the participating vocational schools, and informed consent was obtained from all student participants and/or their guardians.

AI Statements

This article is the original work of the author without using AI tools for writing sentences and/or creating/editing tables and figures in this manuscript.

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