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The Effectiveness of Augmented Reality-Based Simulation Media for Fiber Optic Splicing in Vocational Network Technology Education

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Abstract: This study aimed to develop and evaluate an Augmented Reality (AR)-based simulation media for teaching fiber optic splicing in vocational network technology education. Using a Research and Development (R&D) approach with the 4D model (Define, Design, Develop, Disseminate), the product was validated by experts and tested for practicality and effectiveness through a one-group pretest–posttest design. The media obtained high validity scores (Aiken's V = 0.85 for media and 0.97 for material), was categorized as very practical by teachers (98.31%) and students (89.52%) and showed significant improvement in learning outcomes (N-gain = 0.7115; $p < 0.05$). Unlike previous AR studies that mainly focus on conceptual science learning, this research integrates procedural vocational skills simulation with mobile-based AR to address limited access to expensive splicing equipment. The findings indicate that AR-based simulation can effectively enhance students' procedural understanding and support technology-integrated vocational pedagogy.

Keywords: Augmented Reality; Simulation Media; Fiber Optic Splicing; Vocational Education

Introduction

Quality education is a key factor in building an advanced and prosperous nation (Hamdani et al., 2022). In Indonesia, vocational high schools play an essential role in producing skilled graduates who are ready to enter the workforce. The vocational high schools curriculum is specifically designed to facilitate relevant learning, ensuring that graduates possess competencies aligned with the needs of industry (Suyitno, 2020). In this context, the integration of technology in vocational education is not merely supportive but essential to ensure that students acquire both theoretical knowledge and industry-relevant technical skills (Suparyati & Habsya, 2024).

Technology integration in education has been widely recognized as a means to enhance interactivity, visualization, and student engagement. In education not only improves access to information but also enhances teaching methods and provides more interactive and engaging learning experiences for students (Jenita et al., 2023). In vocational schools, technology integration is particularly important to help students understand complex and procedural concepts more effectively (Mayasari et al., 2021).

In the context of 21st-century learning, technology integration is supported by the TPACK framework (Technological Pedagogical Content Knowledge), which combines content knowledge, pedagogical knowledge, and technological knowledge (Oktaviana & Yudha, 2022). By applying TPACK, teachers can develop learning materials that are not only aligned with the curriculum but also integrate technology to create more engaging and effective learning environments for students (Rahma et al., 2024). Through TPACK, teachers are encouraged to design instructional strategies that meaningfully integrate technology to support skill-

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based learning rather than merely delivering content. However, many vocational schools still face challenges in fully utilizing technology to support teaching and learning activities (Aprianka et al., 2021).

SMK Negeri 1 Lembah Melintang is one of the leading vocational schools in Pasaman Barat, offering eight majors, including Computer and Network Engineering (TKJ). Each program is designed to provide specialized education relevant to specific industries. Despite its competitive programs, the school has not fully optimized the use of technology in the learning process, which limits students' potential.

SMK Negeri 1 Lembah Melintang is one of the vocational schools in Pasaman Barat, offering several majors, including Computer and Network Engineering (TKJ). In this program, mastery of practical competencies is crucial to ensure students' readiness for industrial work environments. Based on observations and interviews with teachers in the TKJ department, especially in grade XI, one critical topic taught in the Wired and Wireless Network Technology subject is fiber optic splicing—a vital technique in the installation of fiber optic networks (Irnando et al., 2019). However, the teaching of fiber optic splicing encounters major constraints, primarily the limited availability of splicing devices, which are costly (reaching tens of millions of rupiah per unit). The school only has one device for a class of 32 students, hindering optimal practice and limiting student understanding of the procedure.

To overcome this issue, a promising solution is the development of a simulation-based learning media using Augmented Reality (AR). AR technology enables students to virtually practice fiber optic splicing using more accessible tools, such as smartphones or tablets. Research by Utama et al., (2024) highlights that AR can significantly improve students' conceptual understanding and practical skills by providing an interactive learning environment.

Previous studies have shown that AR can substantially enhance the quality of learning. A meta-analysis by Prasetya et al., (2024) found that AR-based learning improves content relevance, student attention, and satisfaction. These findings confirm that AR has great potential to address the limitations posed by the high cost of physical equipment (Ashari et al., 2022).

However, most previous AR studies predominantly focus on conceptual learning in science and mathematics rather than procedural technical competencies in vocational education. Furthermore, limited research specifically examines the use of mobile-based AR to simulate high-cost industrial equipment, such as fiber optic splicing devices. This indicates a research gap in the application of AR for procedural skill development within vocational network technology education.

Therefore, the development of AR-based simulation media for fiber optic splicing in the Wired and Wireless Network Technology subject at SMK Negeri 1 Lembah Melintang is expected to provide an effective solution. By integrating AR technology into the classroom, students can gain deeper understanding and hands-on experience, better preparing them to meet industry demands. The novelty of this study lies in integrating mobile-based AR simulation specifically designed for procedural fiber optic splicing training, aimed at overcoming equipment limitations while aligning with the TPACK framework in vocational education.

Method

This study employed a Research and Development (R&D) approach to develop and evaluate an Augmented Reality (AR)-based simulation media. R&D is commonly used to produce educational products and test their feasibility and effectiveness (Sugiyono, 2014). In educational research, this approach emphasizes the development of practical instructional tools rather than purely theoretical studies (Gall et al., 2003). Development research also aims to strengthen the empirical foundation of instructional design (Ainin, 2013). According to Richey and Klein (2007), In addition, it is intended to solve practical problems in educational settings and improve learning effectiveness.

The development process adopted the 4-D model (Define, Design, Develop, Disseminate) introduced by Thiagarajan and Semmel (Sari, 2024). This model provides a systematic and structured framework for instructional media development and is frequently applied in educational product research (Maydiantoro, 2021). In the Define stage, a needs analysis was conducted at SMK Negeri 1 Lembah Melintang, particularly in the Computer and Network Engineering program. The analysis revealed limited availability of fiber optic splicing equipment, lack of interactive learning media, and students' difficulties in mastering procedural competencies. In the Design stage, learning objectives were formulated in accordance with the competencies of the Wired and Wireless Network Technology subject. The media design included 3D models of fiber optic components, step-by-step splicing animations, AR markers in the form of QR codes, and a supporting printed module.

In the Develop stage, the AR application was created using Unity3D and AR technology. The product underwent expert validation involving two media experts and two subject-matter experts. The validation instrument assessed content accuracy, language clarity, instructional design, visual quality, and technical functionality based on media evaluation criteria (Arsyad, 2010). Revisions were made according to expert feedback before field testing.

The effectiveness testing employed a pre-experimental one-group pretest–posttest design (Sugiyono, 2014). Students completed a pretest prior to using the AR media and a posttest after the learning session. The research subjects consisted of 2 lecturers and 2 vocational teachers for expert validation. Although 24 Grade XI students participated in the implementation phase, only 24 students completed both the pretest and posttest and were included in the effectiveness analysis, consistent with the degrees of freedom reported in the paired sample t-test results.

The instruments included validation sheets, practicality questionnaires, and multiple-choice cognitive tests (Arikunto, 2010). Item validity was calculated using point biserial correlation, and reliability was measured using the Kuder–Richardson Formula 20 (KR-20) (Arikunto, 2010). The final test consisted of 22 valid items with a reliability coefficient of 0.885, indicating high internal consistency. Item difficulty index and discriminating power were also analyzed to ensure balanced test quality.

Data analysis was conducted using three indicators. First, classical completeness was determined based on the percentage of students achieving the minimum passing score of 75, with a reference threshold of 85%(Al-Tabany, 2017). Second, normalized gain (N-gain) was calculated to measure the level of learning improvement (Hake, 1999). Third, a paired sample t-test was performed to determine statistical significance. Prior to hypothesis testing, data normality was examined using the Shapiro–Wilk test in SPSS version 29 at a significance level of 0.05.

Result and Discussion

Result

1. Product Development Results

The development of the Augmented Reality (AR)-based simulation media for fiber optic splicing was carried out through four stages of the 4D model: Define, Design, Develop, and Disseminate. In the Define stage, a needs analysis was conducted through interviews and classroom observations in the Computer and Network Engineering program at SMK Negeri 1 Lembah Melintang. It was found that the learning process, particularly in the material of fiber optic splicing, faced several issues such as the lack of supporting tools and media, which made it difficult for students to comprehend both theoretical and practical aspects. Only one splicing device was available for a class of 32 students, which was not sufficient for hands-on practice. Additionally, the learning process was not engaging, which led to decreased student motivation. However, all students owned Android smartphones, and this became a potential foundation for integrating AR as a solution to create more interactive and accessible learning media. The aim of this innovation was to help students visualize and simulate fiber optic splicing steps using mobile AR-based learning tools.

In the Design stage, the learning objectives were aligned with the subject matter of Wired and Wireless Network Technology based on the Merdeka Curriculum. The media was designed to include several components such as 3D models of fiber optic cables, splicing animations, AR markers in the form of QR codes, quizzes, and supporting learning materials compiled into a printed module. The application interface included a splash screen, menu navigation, module content display, and a quiz section. In addition, an instructional module containing scan markers and theory sections was prepared to assist students in accessing the content. The use of AR markers allowed students to scan printed materials and interact directly with 3D visualizations, facilitating contextual and spatial learning.

During the Develop stage, the application was built using Unity 3D software and the AR Foundation plugin. Realistic and interactive 3D models and animations were developed to simulate fiber optic splicing procedures. After internal testing, the media was validated by two material experts and two media experts. Feedback from these experts was used for revisions before classroom trials. Subsequently, limited field testing was carried out with 24 students and 1 subject teacher. The learning media was accompanied by a printed module containing learning materials and marker pages. This integration was intended to support students' ability to both follow theoretical explanations and access simulated practices.

In the Disseminate stage, the finalized AR media was introduced in actual classroom instruction. Training was provided to the subject teacher to facilitate media implementation. Students used the media both in class and independently. The integration of AR was not only aimed at addressing the limitations in physical equipment but also to prepare students to be more independent and ready to apply practical skills in real-world scenarios.

2. Media Validation Results

Validation of the media was conducted using expert judgment to determine whether the product met the standards required for instructional media. Media validation focused on three main components: media design, software performance, and usefulness. The results showed that the AR media had a high level of validity. According to the two media experts, the average Aiken's V value was 0.85, categorized as valid. Similarly, validation by material experts yielded an average Aiken's V score of 0.97, also in the valid category.

Table 1. Media Expert Validation

Aspect	Score	Category
Media Design	0.85	Valid
Software	0.85	Valid
Usefulness	0.84	Valid
Average	0.85	Valid

Table 2. Material Expert Validation

Aspect	Score	Category
Content Accuracy	0.97	Valid
Visual Presentation	0.96	Valid
Instructional Use	0.98	Valid
Average	0.97	Valid

3. Media Practicality Results

To evaluate practicality, responses were collected from 1 teacher and 24 students using structured questionnaires. The evaluation considered aspects such as usability, clarity, design appeal, content structure, and ease of access. The teacher's response showed an average score of 98.31%, placing the media in the "Very Practical" category. The teacher noted that the media was easy to operate, informative, and capable of helping students better understand fiber optic splicing.

Students also gave positive responses. Their average score was 89.52%, indicating the media was very practical for use in learning. Most students stated that the AR simulation helped them visualize splicing steps clearly, and the flexibility of being able to learn independently through smartphones added significant value.

Table 3. Practicality Scores

Respondent	Score (%)	Category
Teacher	98.31%	Very Practical
Students	89.52%	Very Practical

4. Effectiveness Results

Effectiveness was analyzed using pre-test and post-test comparisons, following a one-group pretest-posttest design. The test consisted of 22 validated multiple-choice items, with a minimum passing score of 75. The results showed that 23 out of 24 students (95.83%) reached the minimum completeness level, categorized as "very good." The normalized gain score (N-Gain) was calculated using the Hake (1999) formula. The result was 0.7115, which falls into the "High" category.

Table 4. N-Gain Score Result

Category	N-Gain	Interpretation
Class XI TKJ	0.7115	High

The data were further analyzed using paired sample t-test to determine whether the improvement was statistically significant. The results showed a t-value of 14.051, Sig. (2-tailed) = 0.000, and df = 23. The paired sample t-test showed a statistically significant difference ($p < 0.05$).

Discussion

The findings suggest that the developed Augmented Reality (AR)-based simulation media fulfills essential criteria of instructional feasibility, including validity, practicality, and effectiveness in vocational learning contexts. The high validation scores indicate that the media met technical, pedagogical, and curriculum alignment standards. Validation is an important stage in development research to ensure that a product is appropriate for classroom implementation (Andrian, 2020). In addition, effective learning media should be visually engaging, readable, and capable of motivating students (Muhayat et al., 2019), The validation results imply that the developed AR media satisfied these core instructional requirements.

From a practicality perspective, the positive responses from teachers and students reflect that the media was easy to operate and supportive of learning objectives. Practicality is commonly associated with usability, clarity, and the ability of media to facilitate instructional goals. who argued that practicality is measured by ease of use, clarity, and the media's ability to support instructional goals (Purnomo, 2021). Moreover, interactive and mobile-friendly learning tools are considered particularly suitable for vocational and technical education settings (Guntur & Setyaningrum, 2021). The strong practicality results may be influenced by the familiarity of students with smartphone-based applications, which reduced technical barriers during implementation. In addition, learning media that are simple, time-efficient, and engaging tend to increase student motivation (Insani & Body, 2021), which may explain the positive reception observed in this study.

Regarding effectiveness, the high classical completeness rate (95.83%), substantial N-gain score (0.7115), and statistically significant improvement between pretest and posttest scores indicate meaningful learning gains. According to Hake (1999), gain scores above 0.7 represent high learning improvement, suggesting that the AR simulation contributed to enhanced conceptual understanding. Similar findings have been reported in vocational education contexts, where AR-based simulations improved student comprehension and engagement (Herlandy et al., 2020). The use of interactive 3D visualization likely supported students in understanding procedural steps that are typically difficult to grasp through conventional explanation alone.

The integration of AR technology into fiber optic instruction is particularly relevant in environments with limited access to physical laboratory equipment. AR has been identified as an effective tool for supporting procedural and practice-oriented learning when direct access to tools is restricted (Pipattanasuk & Songsriwittaya, 2020). By utilizing smartphones already owned by students, the developed media provided a flexible and accessible alternative for practical learning. Furthermore, the integration of content, pedagogy, and technology in this development reflects the principles of the TPACK framework (Rahma et al., 2024; Oktaviana & Yudha, 2022), enabling a more contextual and technology-enhanced learning experience. The visual and interactive features of AR may also support learners who experience difficulty in abstract conceptualization, as noted by Ariansyah (2022).

Despite these positive findings, several limitations should be considered. The study employed a one-group pretest–posttest design without a control group, which limits the ability to attribute learning gains solely to the AR intervention. Other factors, such as prior knowledge, teacher guidance, or independent practice, may have influenced the results. In addition, the sample consisted of only 24 students from a single vocational school, which restricts the generalizability of the findings. Future research should employ experimental designs with control groups, larger sample sizes, and longer implementation periods to strengthen causal inference and evaluate long-term impacts on skill mastery and industry readiness.

Overall, the findings indicate that AR-based simulation media demonstrates strong potential as an alternative instructional tool in vocational education, particularly in contexts where physical infrastructure is limited.

Conclusion

Based on the results of development, testing, and analysis, it can be concluded that the Augmented Reality (AR)-based simulation media for fiber optic splicing is valid, practical, and effective for use in vocational education, specifically in the Wired and Wireless Network Technology subject. The media development followed the 4D model (Define, Design, Develop, Disseminate) and successfully addressed the identified instructional problems, particularly the lack of splicing equipment and limited interactive learning resources.

The validity results from expert evaluations confirmed that the content, design, and technical functionality of the AR media met the required standards, with Aiken's V scores of 0.85 (media experts) and 0.97 (material experts). The practicality results showed that both teachers and students found the media to be highly usable, with scores of 98.31% and 89.52%, respectively, placing it in the "very practical" category. Moreover, the media was proven effective, with 95.83% of students achieving classical completeness, an N-Gain score of 0.7115 (high category), and a statistically significant improvement in post-test results ($t = 14.051$, $p < 0.05$).

This media serves as a viable instructional tool that supports visualization, student autonomy, and accessibility especially in schools with limited infrastructure. By leveraging AR technology through devices already owned by students, the media enables practical learning experiences that bridge theoretical concepts with technical skills.

In addition to its effectiveness, this development carries several important implications for vocational education. For teachers, it provides an alternative medium to enhance clarity in instruction and reduce dependence on limited physical tools, supporting the creation of more interactive and engaging learning environments. The integration of AR into teaching also aligns with the TPACK framework, enabling a balanced use of technological, pedagogical, and content knowledge.

For students, the media promotes self directed and repeated practice through accessible simulations on their own smartphones, helping to strengthen both conceptual understanding and hands-on competence. This approach is well suited to Generation Z learners who are familiar with digital interaction and multimedia-based environments.

At a broader level, for schools and policymakers, the AR-based media presents a scalable and cost effective solution to infrastructure constraints, particularly in under resourced or rural areas. It aligns with the Merdeka Curriculum's goals of fostering digital literacy, student-centered learning, and differentiated instruction through technology integration. Furthermore, this innovation opens potential for adaptation to other vocational fields and integration into learning management systems (LMS), enabling more personalized learning and progress tracking. Future research may explore its long-term impacts on student motivation, performance, and industry readiness

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Conflicts of Interest

The author declares no conflict of interest.

References

Ainin, M. (2013). Penelitian Pengembangan Dalam Pembelajaran Bahasa Arabi. *Okara: Jurnal Bahasa Dan Sastra*, *2*(8), 96–110.

Al-Tabany, T. I. B. (2017). *Mendesain model pembelajaran inovatif, progresif, dan konteksual*. Prenada Media.

Andrian, J., & Maksum, H. (2020). Development of Android-Based Learning Media in The Subjects of Planning and Installation Video Audio System. *EDUTEC: Journal of Education And …*, *3*(2), 193–203.

Aprianka, S., Setiani, A., & Imswatama, A. (2021). Validitas E –Modul Berbasis Open Ended Meteri Sistem Persamaan Linear Dua Variabel Pada Pembelajaran Daring untuk Siswa SMK. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *5*(3), 3111–3122. https://doi.org/10.31004/cendekia.v5i3.896

Ariansyah, F., Septiati, E., & Octaria, D. (2022). Pengembangan Media Pembelajaran Interaktif Berbasis Android pada Materi Peluang untuk Siswa SMA. *Indiktika : Jurnal Inovasi Pendidikan Matematika*, *4*(2), 36–48. https://doi.org/10.31851/indiktika.v4i1.7120

Arikunto, S. (2010). Prosedur penelitian suatu pendekatan praktek. In *(No Title)*.

Arsyad, A. (2010). *Media Pembelajaran*. Rajawali P.

Ashari, S. A., A, H., & Mappalotteng, A. M. (2022). Pengembangan Media Pembelajaran Movie Learning Berbasis Augmented Reality. *Jambura Journal of Informatics*, *4*(2), 82–93. https://doi.org/10.37905/jji.v4i2.16448

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). Educational Research: An Introduction (7th ed.). In *Qualitative Voices in Educational Research* (pp. 1–68). Allyn & Bacon. https://doi.org/10.4324/9781003008064-1

Guntur, M. I. S., & Setyaningrum, W. (2021). The Effectiveness of Augmented Reality in Learning Vector to Improve Students' Spatial and Problem-Solving Skills. *International Journal of Interactive Mobile Technologies*, *15*(5), 159–173. https://doi.org/10.3991/ijim.v15i05.19037

Hake, R. R. (1999). Analyzing change/gain scores. *Unpublished.[Online] URL: Http://Www. Physics. Indiana. Edu/\~ Sdi/AnalyzingChange-Gain. Pdf*, *16*(7), 1073–1080. http://www.ncbi.nlm.nih.gov/pubmed/22025883%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:ANALYZING+CHANGE/GAIN+SCORES#0%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Analyzing+change/gain+scores#0

Hamdani, A. D., Nurhafsah, N., & Silvia, S. (2022). Inovasi Pendidikan Karakter Dalam Menciptakan Generasi Emas 2045. *JPG: Jurnal Pendidikan Guru*, *3*(3), 170. https://doi.org/10.32832/jpg.v3i3.7291

Herlandy, P. B., Azim, F., & Majid, N. W. A. (2020). The effectiveness of Augmented Reality based Learning on Vocational Competencies of Vocational School Students. *Edumatic: Jurnal Pendidikan Informatika*, *4*(2), 120–128. https://doi.org/10.29408/edumatic.v4i2.2653

Insani, P., & Body, D. R. (2021). Pengembangan Media Pembelajaran Mobile Learning Berbasis Android Pada Mata Pelajaran Gambar Teknik di SMK Negeri 1 Bukittinggi. *Applied Sciences In Civil Engineering (ASCE)*, *2*(3), 325–333.

Irnando, A., Wanda, R., Muhamad, A. E., & Prita, D. (2019). Pengembangan Media Pembelajaran Virtual Reality Pada Materi Pengenalan Termination Dan Splicing Fiber Optic. *Jurnal Dimensi Pendidikan Dan Pembelajaran*, *3800*.

Jenita, Harefa, A. T., Pebriani, E., Hanafiah, Rukiyanto, B. A., & Sabur, F. (2023). Pemanfaatan Teknologi Dalam Menunjang Pembelajaran: Pelatihan Interaktif Dalam Meningkatkan Kualitas Pendidikan. *Communnity Development Journal*, *4*(6), 13121–13129.

Mayasari, A., Pujasari, W., Ulfah, U., & Arifudin, O. (2021). Pengaruh Media Visual Pada Materi Pembelajaran Terhadap Motivasi Belajar Peserta Didik. *Jurnal Tahsinia*, *2*(2), 173–179. https://doi.org/10.57171/jt.v2i2.303

Maydiantoro, A. (2021). Model-Model Penelitian Pengembangan (Research and Development). *Respository LPPM Unila*, *10*, 1–8. http://repository.lppm.unila.ac.id/34333/1/Model-Model Penelitian dan Pengembangan.pdf

Muhayat, U., Wahyudi, W., Wibawanto, H., & Hardyanto, W. (2019). Pengembangan Media Edukatif Berbasis Augmented Reality untuk Desain Interior dan Eksterior. *Innovative Journal of Curriculum and Educational Technology*, *6*(2), 39–48.

Oktaviana, E., & Yudha, C. B. (2022). Tecnological Pedagogical Content Knowledge (TPACK) Dalam Pembelajaran Abad Ke-21. *Social, Humanities, and Educational Studies (SHEs): Conference Series*, *5*(2), 57. https://doi.org/10.20961/shes.v5i2.58305

Prasetya, F., Fortuna, A., Samala, A. D., Rawas, S., Mystakidis, S., Syahril, Waskito, Primawati, Wulansari, R. E., & Kassymova, G. K. (2024). The impact of augmented reality learning experiences based on the motivational design model: A meta-analysis. *Social Sciences and Humanities Open*, *10*(May), 100926. https://doi.org/10.1016/j.ssaho.2024.100926

Purnomo, J., & Nuryanto, A. (2021). Pengembangan Media Pembelajaran Berbasis Aplikasi Android untuk Mata Pelajaran Teori Pemesinan Gerinda. *Jurnal Pendidikan Vokasional Teknik Mesin*, *9*(1), 81–86.

Rahma, F. I., Yumnah, S., & Rokim, R. (2024). Analisis Kemampuan TPACK (Technological, Pedagogical, and Content Knowledge) Guru Matematika melalui Rencana Pelaksanaan Pembelajaran. *Dawuh Guru: Jurnal Pendidikan MI/SD*, *4*(1), 31–46. https://doi.org/10.35878/guru.v4i1.1087

Sari, D. S. (2024). Pengembangan Lembar Kerja Peserta Didik Berbasis Model Kooperatif Tipe Jigsaw pada Pembelajaran Tematik Tema Benda-Benda di Sekitar Kita di Kelas V SD. *Journal on Educatio*, *06*(03), 16707–16719.

Sugiyono. (2014). *Metode Penelitian Kuantitatif, Kualitatif dan R&D* (19th ed.). ALFABETA.

Suparyati, A., & Habsya, C. (2024). Kompetensi Lulusan Pendidikan Vokasi untuk Bersaing di Pasar Global. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *7*(2), 1921–1927. https://doi.org/10.54371/jiip.v7i2.3288

Suyitno. (2020). *Pendidikan Vokasi Kejuruan Srategi dan Revitalisasi Abad 21*.

Utama, K. W., Rahayu, M. K., Azizah, L. F., Winarti, Sitopu, J. W., & Wiliyanti, V. (2024). Pengaruh Penggunaan Teknologi Augmented Reality Dalam Pembelajaran Ipa Terhadap Pemahaman Materi Pembelajaran. *Jurnal Review Pendidikan Dan Pengajara*, *6*(3), 7813–7821. https://www.medigraphic.com/pdfs/educacion/cem-2017/cem172y.pdf