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Development of AR-Based Learning Media for Sensor and Actuator Subjects using Assemblr Edu

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Abstract - Low student engagement and limited understanding in the subject of Sensor and Actuator Devices remain a challenge at State Vocational High School (SMKN) 5 Padang. These issues are partly caused by minimal integration of technology and the continued use of conventional learning tools. Augmented Reality (AR)-based media such as Assemblr Edu, which allows real-time visualization of 3D objects, have not been widely utilized. In response, this study aims to develop interactive AR-based learning media using Assemblr Edu that is valid and practical for classroom use. The research employed the 4-D development model: Define, Design, Develop, and Disseminate. Validation was conducted by six experts—three media experts and three subject matter experts. The subject matter validation resulted in a score of 95.5% ("Very Valid"), while the media validation reached 92.95% ("Very Valid"). A usability test involving 20 eleventh-grade students from the Industrial Electronics Technology (TEI) program showed a score of 95.55% ("Very Practical"). The developed media also increased students' interest and motivation. These results indicate that the AR-based learning media is highly valid and practical for enhancing teaching and learning in the Sensor and Actuator Devices subject at SMKN 5 Padang.

Keywords — Learning Media; Augmented Reality; Assemblr Edu; Sensor Devices, Actuator Devices.

I. INTRODUCTION

The industrial landscape has changed as a result of the digital transformation triggered by advances in information and communication technology [1]. The development of new industrial frameworks and strategies, including the concepts of Made in China 2025, Industrial Internet, and Industrial Revolution 4.0, has been influenced by this wave of change. Significant changes in society have occurred due to the complexity of Internet of Things (IoT) technology, artificial intelligence (AI), and robotics in the industrial sector [2].

These technologies enable humans to replace physical labor and solve social problems more quickly and easily [3]. Ultimately, this phenomenon has given rise to the idea that humans and technology can coexist to provide a more meaningful life [4]. Japan created Society 5.0, the main idea of the Fifth Science and Technology Basic Plan, based on this way of thinking [5].

The rapid advancement of research and innovation has given rise to the era of Society 5.0. This stage of civilization is characterized by a human-centered society that integrates advanced technologies to create a more inclusive and sustainable environment. Unlike the Industrial Revolution 4.0, which primarily emphasized the growth of business and personal efficiency, Society 5.0 aims to generate new values that address societal needs and reduce social disparities [6].

The era of society 5.0 has an effect on areas of the world such as digital technology, artificial intelligence, big data, robotics and augmented reality [7]. One of the fields affected by society 5.0 is education in Indonesia.

There are several ways to deal with learning in Indonesia's society 5.0 period, one of which is that educators must be able to have skills, master, and utilize technology in the process of learning [8]. This is consistent with Permendikbud No. 16 of 2007, namely an educator must have the ability to use technological innovation for quality in the learning process. Furthermore, this statement is further strengthened by Pemendikbud No. 22 of 2016 regarding process standards, namely that a teacher must be able to involve advances in information technology so that the quality of learning can be better [9].

Generation Z, who grew up in the digital era, has unique characteristics. They quickly adapt to technology, want instant access to information, and are more interested in visual and interactive content. Seemiller and Grace's (2016) research shows that 90% of Generation Z feels disturbed if they lose internet access [10]. This shows the need for learning technology that can fulfill this generation's preferences. One of the technologies that can integrate real and virtual worlds in real-time is AR, Such technologies integrate digital information and virtual elements into real-world environments, enhancing the learning experience and providing students with

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interactive and immersive activities [11]. This technology facilitates the development of learning media that can display not only two-dimensional objects, but also three-dimensional models, videos, and audio, all of which can be accessed via smartphones and computers [12] .

AR-based learning media plays a significant role in supporting the attainment of learning objectives, especially in delivering material that requires more real visualization [13]. This technology allows students to be actively involved through exploration and interaction with virtual objects. By combining the real world and the digital world, AR helps students understand teaching materials more contextually. Abstract concepts that are difficult to explain verbally can be visualized in three-dimensional (3D) form, providing a concrete and engaging learning experience. The integration of AR in learning not only increases the effectiveness of material delivery, but also creates a learning experience that is more relevant to technological developments [14].

The use of AR in learning media provides new opportunities to create a more interactive and real learning experience. Abstract concepts can be visualized in 3D making it easier to understand than conventional methods. For example, in learning sensor and actuator devices, AR models can interactively display selonoid valves or proximity sensors, so that students can observe and manipulate digital objects from various points of view. AR also allows students to explore and manipulate digital objects in three-dimensional space, providing more immersive learning opportunities [15]. With these interactive features, students are not only recipients of information, but can also experiment and explore the material independently. According to Akçayır & Akçayır (2017), the use of AR in education can increase student motivation and engagement during the learning process.

However, although AR has great potential, challenges in improving student learning outcomes still exist, especially in the implementation of Merdeka Curriculum which emphasizes active student participation. One of the main problems is the lack of efficient supporting media to maximize student engagement in learning activities. In addition, there are still students who struggle to maintain motivation and interest in the material being taught. This is also expressed by [16], who stated that technical constraints and lack of resources can limit the effectiveness of AR in learning.

This research aims to address the shortcomings of traditional learning methods, particularly in the Sensor and Actuator Devices subject. Based on the Learning Objective Completeness Criteria (KKTP), only 64.29% of students have achieved the minimum competency standard. One contributing factor is the continued use of conventional learning media, which fails to attract and sustain student interest. To overcome this, AR-based learning media was developed using the Assemblr Edu platform. By incorporating augmented reality into the learning process, this media aims not only to improve the quality of learning but also to respond to the demands of the Merdeka Curriculum, which emphasizes active, innovative, and relevant learning experiences. The gap in student engagement and achievement is further illustrated in Table 1, which presents the student learning participation scores as a baseline prior to the intervention.

TABLE 1
STUDENT LEARNING PARTICIPATION SCORES

Class	Number Of Studens	KKTP Value				Average Value
		Grades ≥ 75,00		Grades ≥ 75,00		
		Number Of Studens	%	Number Of Studens	%	
XI TEI	28	18	64,29%	10	35,71 %	72,67

Based on student scores in Table 1, there are still 10 students who scored below the KKTP, as seen from the average score of students who have not reached the standard. Based on the explanation in Table 1 above, new innovations are needed in the teaching and learning process to meet the KKTP score standards.

Based on these problems, researchers developed learning media by utilizing facilities at SMK Negeri 5 Padang, including a computer laboratory with 24 PCs and Android phones owned by each student. Previous studies have shown that testing this AR learning media can improve student learning outcomes and address the challenges at SMK Negeri 5 Padang. Available resources support the implementation of this flexible media, which can be used online or offline without time constraints. This media can be accessed not only through laptops, but also through smartphones by teachers and students [17].

II. METODHS

Development research is the methodology used in this study. The 4-D model, a framework for developing instructional tools first introduced by [18], was applied using a structured development research approach. This model comprises four key stages: Define, Design, Develop, and Disseminate. Each stage outlines specific activities to ensure the systematic development of learning media. The research design applied in this study is presented in Figure 1, which illustrates the overall 4-D development process and the corresponding steps undertaken during each phase of the research.

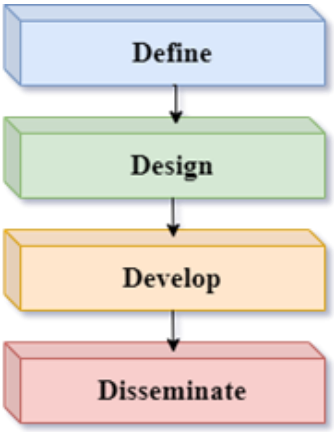

Fig 1. Development Method Design Using the 4-D Model

Compared to other development models, such as Dalam paradigma Dick dan Carey, ADDIE merupakan singkatan dari Analisis, Desain, Pengembangan, Implementasi, dan Evaluasi. After this AR-based learning media is developed, the product

will be tested through validation by media experts and material experts as well as field trials on class XI TEI students at SMK Negeri 5 Padang. This trial aims to measure the level of validity and practicality of the learning media, especially in improving student learning outcomes and motivation.

This development research applies the 4-D model, which consists of four stages: Define, Design, Develop, and Disseminate. The detailed research steps at each stage are shown in Figure 2, adapted from the model introduced in [18].

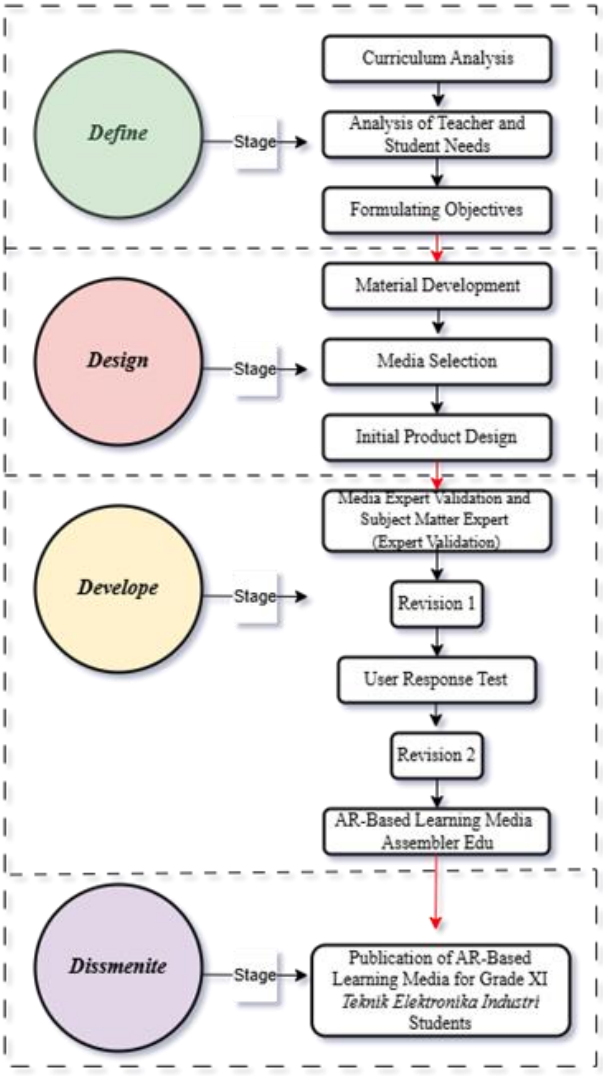

Fig 2. Research procedure flowchart.

The following is a description of the stages of the 4D procedure:

A. The Define stage

The Define stage aims to establish learning requirements, which support analyzing the needs of students. Researchers determine the product to be developed and its specifications through a needs analysis involving research and literature studies and direct observation in class XI of SMK Negeri 5 Padang in the subject of sensor and actuator devices. SMK Negeri 5 Padang applies the Merdeka Curriculum, which emphasizes gaining knowledge of results and the improvement of vital abilities in step with the times, Enables schools and teachers to create contextual and meaningful learning experiences. Material analysis aims to identify content that needs to be developed using AR Learning media, based on observations and interviews with teachers, and review the curriculum to sort out material that is in accordance with the learning objectives in the Merdeka Curriculum. The formulation of learning objectives is important to maintain the focus of the research, with the objectives set must be in accordance with curriculum analysis, student needs, and materials that have been analyzed, thus limiting the scope of material in AR learning media.

B. The design phase

The design phase aims to create the learning media using the Assemblr Edu application, supported by additional tools such as Blender and YouTube. In this phase, the program structure, visual style, interface, and necessary components are planned in detail. The design plan uses the display interface of the application menu as the basis for developing the overall layout. Figure 3 shows the flowchart used to guide the design of the learning media in this phase.

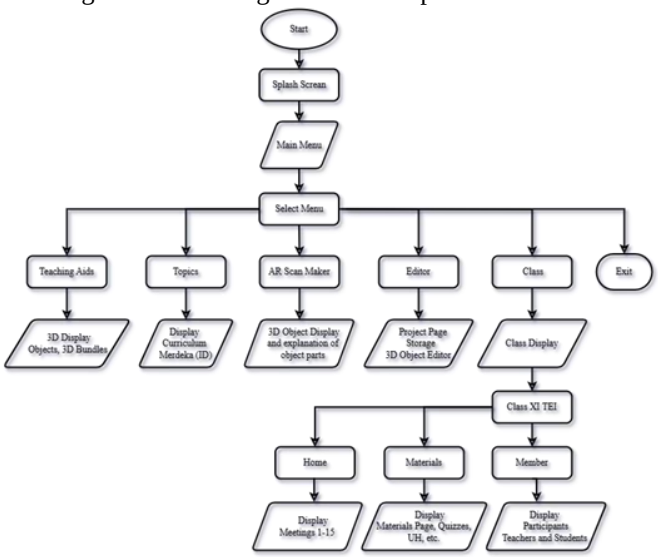

Figure 3. Flowchart.

C. The development stage

The development stage was carried out by validating the AR-based learning media with both expert and empirical validators. Expert validators consisted of three media experts and three material experts, while empirical validation was conducted with 20 eleventh-grade TEI students and one subject teacher of Sensor and Actuator Devices. The validation results were then used to revise and improve the media to better suit user needs. The expert team included three lecturers from the Department of Electronic Engineering at Padang State University and three TEI teachers from SMKN 5 Padang. Specifically, two lecturers and one teacher acted as media experts, while one lecturer and two teachers served as material experts. A structured questionnaire was used in the validation process to assess the media's validity.

To collect research data, a questionnaire was used with a five-point Likert scale to measure students' responses. Table 2 presents the scoring criteria, using a range from "Very Good" to "Not Very Good," represented by codes and corresponding numeric values. These criteria helped standardize interpretation during data analysis.

TABLE 2
ANSWER SCORE CRITERIA

SS	Very good	(5)
S	Good	(4)
KB	Less Good	(3)
TB	Not good	(2)
STB	Not very good	(1)

The scoring system shown in Table 2, adapted from [19], was used to quantify student responses to the questionnaire items. Each response was assigned a numeric value based on its position on the Likert scale, allowing for a more objective analysis of the data collected. The data obtained from the validity questionnaire was analyzed using a percentage scale (0%–100%) based on the following formula:

$$V = \frac{X}{Y} \times 100\%$$

Description:
V = indicates the level of validity
X = Score achieved
Y = Maximum points

To assess the validity of the developed learning media, expert judgment was categorized based on achievement rates. Table 3 shows the categories used to interpret the validity score percentages, ranging from "Invalid" to "Very Valid," adapted from [20]. These categories served as a reference for determining the overall level of media validity based on expert evaluations.

TABLE 3
VALIDITY ASSESSMENT CATEGORIES

Achievement Rate (%)	Category
0% ≤ 20%	Invalid
21% ≤ 40%	Less valid
41%≤ 60%	Valid enough
61% ≤ 80%	Valid
81% ≤ 100%	Very valid

D. The Dissemination stage

The Dissemination stage represents the final phase of the research and development model, which aims to demonstrate the practicality of Augmented Reality (AR)-based learning media in the subject of Sensors and Actuators. In this study, dissemination activities were carried out on a limited basis, which only involved related subject teachers at SMK Negeri 5 Padang as the main target, without being extended outside the school environment. Dissemination includes two main activities, namely the distribution of media products that have been developed and the implementation of practicality trials through direct involvement of students.

During the user testing phase, students from the Industrial Electronics Engineering (TEI) Class XI were involved in using the developed learning materials. This process aimed to evaluate the feasibility and practicality of the media, with a focus on its ease of use and effectiveness in supporting students' understanding of the subject matter. The trial is planned to involve 20 students, and the results of the practicality assessment will be analyzed using validated evaluation instruments and certain predetermined calculation formulas, in order to obtain an objective picture of product quality.

III. RESULT

A. Development Results

The learning media developed using the Assemblr Edu application presents material through three-dimensional animations and Augmented Reality (AR) technology, integrated into the subject of Sensor and Actuator Devices (PSA). This innovation is designed to create a more engaging, interactive, and contextual learning environment, allowing students not only to view visual representations of the material but also to interact directly with digital objects in 3D space. As a result, students experience a more immersive and meaningful form of learning, which is expected to enhance their conceptual understanding and overall engagement. Table 4 displays the visualization outcomes of the AR-based learning media developed using Assemblr Edu for the PSA subject.

TABLE 4
AR PSA MEDIA EDITING VIEW

NAME	SHOW	CONTENTS
Cover Initial view		On the cover there is the name of the media, below which there is a slide menu to go to the Cp-Atp page and the following pages.
Menu CP-ATP		The Cp-Atp display contains a QR code image that can be scanned with Android Google Scan which will lead to opening the file from Cp-Atp.
Material		Material display presents introductory content from the Sensor and Actuator Devices module (P-PSA 1), where students learn to identify types of sensors and actuators.
Video Menu Learning		Learning videos are useful to help learners understand more details about the material presented.

Image Menu 3D Model		The 3D Model view, contains a direct picture of the shape of the sensor and actuator and students can analyze the difference in the actuator sensor.
3D Image Menu How DC Motors Work		A 3D model demonstrating the working principle of a DC motor, including components like coils, rotors, and other typical DC motor parts.
Evaluation Menu		The QR code quiz is clearly displayed in the center, inviting students to scan it. Questions related to PSA learning materials.
Advanced Module Menu and Video Materials…		The Advanced Material display contains learning videos and QR codes that can be scanned. This material is directly related to the next module.

For data collection after the learning media was developed using the Assemblr Edu application in the Sensor and Actuator Devices subject, the following steps were carried out:

A. Validity test by media experts

The media validity test involved three experts: two Electrical Engineering lecturers from Padang State University and one TEI teacher from SMK Negeri 5 Padang. Six aspects were assessed. Clarity of information scored 90%, audio quality 93.33%, visual quality 97.77%, media appeal and interactivity both 96.66%, and the user role aspect 93.33%—all classified as "highly valid." The overall average score was 95.55%, confirming the media's high validity for educational use. The media expert assessment based on the media validity test results in table 3 can be shown in figure 4.

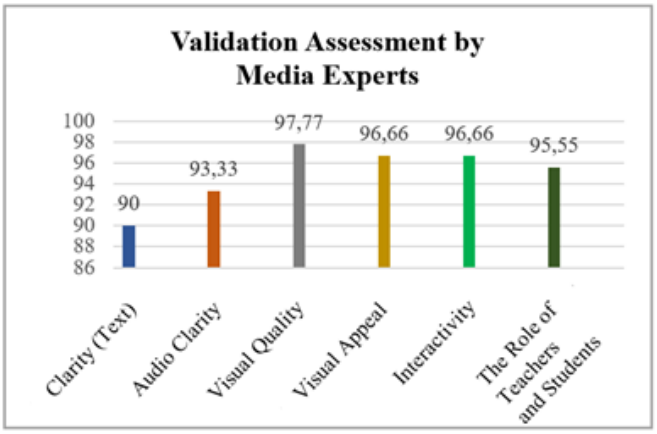

Fig. Graph of Validation Results on the Media Expert aspect

B. Validity Test For Material Experts

Three validators conducted the material expert validation, namely 1 Electronics Engineering lecturer from Padang State University and 2 Electronics Engineering teachers from SMK Negeri 5 Padang. The validity test results obtained through the questionnaire are shown in the following table:

Based on the validation results by the subject matter experts mentioned above, three elements were considered in the evaluation. The first element, content suitability, was rated as highly valid with a score of 91.6%. In the highly valid category, the language component received a score of 84%, while content presentation suitability received a score of 95.5%. With an average percentage score of 91% after validation by subject matter experts, the results meet the criteria for the "highly valid" category. These results indicate that this learning medium can be used as a learning tool. The results of the material expert validation, as detailed in Table 3, are presented visually in Figure 5 to illustrate the scores for each evaluated aspect.

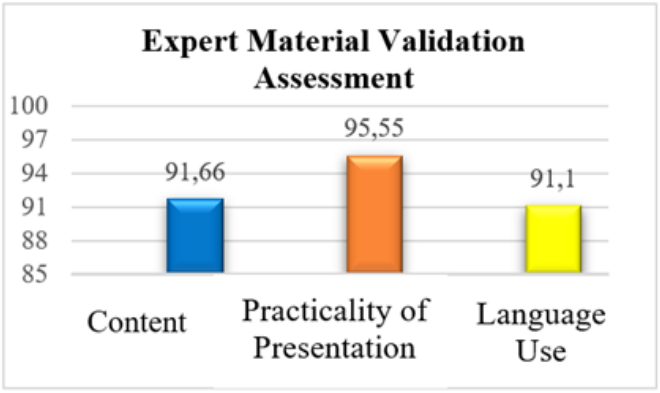

Fig 5. Graph of Validation Results on the Material Expert aspect.

C. Practicality Test

The user trial (practicality test) was aimed at students of class XI TEI SMK Negeri 5 Padang. The practicality test was conducted on a small group of 20 students. The results of the user trial (practicality test) can be seen in Figure 6.

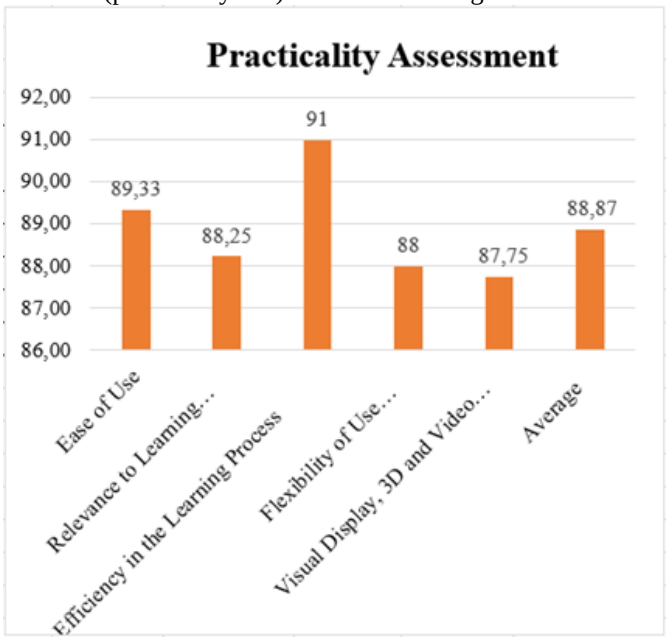

Fig 6. Graph of user test findings

Based on the test finding of user assessment, there are five aspects evaluated in the AR learning media practicality test. The scores obtained are as follows: ease of use 89.33%, compliance with learning 88.25%, efficiency in the learning process 91%, flexibility of use 88%, and visual, 3d, and video display 87.75%. The average score of all aspects is 88.87%, which indicates that this this media is classified as being very useful for education. The graph that follows illustrates the results of the practicality trial.

D. Discussion

The research "Development of Augmented Reality-based Learning Media Assemblr Edu in the Subject of Sensor and Actuator Devices of SMK Negeri 5 Padang" was driven by the limitations of the media used in the teaching and learning the process, in addition to pupils' poor presentation skills. The modern era has seen the emergence of various types of media, including interactive learning media. It can be assumed that learning through learning media will stimulate and motivate students to learn with high motivation, because children are naturally attracted to learning materials that can display text, photos, videos, sounds, and quizzes.

The resource for teaching Sensors and Actuators as Applications for Students in Grade Eleven was designed to improve student achievement in the TEI course at SMK Negeri 5 Padang, using this resource in their learning. Tests and data analysis showed that this curriculum is reliable and useful. Thus, the educational resources can be used to teach Sensor and Actuator applications. Teachers' evaluation of students' progress in Sensors and Actuators will be aided by their exposure to additional media. In addition, the developed learning materials can serve as a template for instructors to create their own learning materials for other texts or as a roadmap for instructors teaching across multiple disciplines. teachers must consider a number of factors when creating interactive learning materials.

In making interactive learning media, It is important for teachers to take into account the key elements and all phases involved in the creation of learning media. Starting from definition, design, and development. Before providing learning materials to students, the materials must be valid and applicable. The validity of the developed teaching materials will be further investigated. Researchers looked at the information provided by the instructor and found that the Learning Media had high validity. The average validity value of the learning media for the Sensor Devices subject area was set at 91% based on the material expert questionnaire, while the average validity value of the media expert was 95.55%. This means that an analysis of the usefulness of electronic circuits in education has been carried out. Through the learning media, it can be concluded that children should be able to learn independently by using a laptop or smartphone. At the end of this media there is also an evaluation that can help students understand their learning outcomes and assess their ability to assimilate new information.

These findings are consistent with Dewi et al. [21], who examined the effect of Augmented Reality (AR) on students' conceptual understanding in the Sensor and Actuator Devices subject. Their quasi-experimental study involving 60 students showed that those taught using AR-based media outperformed students who received traditional instruction. Specifically, the AR group achieved an N-Gain score of 54%, compared to 35% in the control group. The effect size analysis also indicated a substantial impact (d = 1.14), confirming the role of AR in supporting deeper conceptual learning.

Further evidence is presented in Azmi and Hidayat [22], who developed Android-based AR learning media for the Audio Video System Installation Planning (PISAV) course using the MDLC development model. Their product achieved high expert validation results—89.35% for material quality and 98% for media presentation—demonstrating the practicality and effectiveness of AR in vocational learning contexts. These outcomes align with the approach taken in this study, particularly in enhancing student engagement through interactive 3D visualization.

In addition, a study conducted at SMK Hamong Putera 2 Pakem [23] developed AR-based learning media for basic electronics. Expert evaluations of design, materials, and instructional quality yielded a score of 65 out of 80, indicating strong feasibility. Another assessment focusing on software, functionality, and benefits showed an average score of 87 out of 100. Student feedback further confirmed the impact: 55% rated the media as very effective, while 45% considered it adequate. These results further validate the potential of AR-based tools—such as Assemblr Edu—as an effective medium for improving learning quality in vocational education settings.

IV. Conclusion

This This study developed augmented reality (AR)-based learning media for the Sensor and Actuator Devices subject using the Assemblr Edu platform, which featured 3D animations and interactive content. The media was validated by six experts—three media experts (score: 95.55%) and three subject matter experts (score: 91%)—and categorized as “highly valid.” A practicality test with eleventh-grade students resulted in a score of 88.87%, indicating the media was “highly practical” for use in classroom learning.

The main contribution of this study is the integration of AR technology into vocational education to improve student engagement and understanding of abstract technical concepts. The interactive AR features offer a more immersive learning experience that supports both independent and guided instruction. However, the media was limited to selected material within the Sensor and Actuator Devices subject. Future research is encouraged to broaden its scope across more topics, subject areas, and classroom settings, as well as to explore its long-term impact on learning outcomes.

V. References

[1] M. Fukuyama, “Society 5.0: A people-centric super-smart society,” *Soc. 5.0 A People-centric Super-smart Soc.*, no. August, pp. 1–177, 2018, doi: 10.1007/978-981-15-2989-4.

[2] A. Wibowo, *Revolusi Industri 4.0 dan Society 5.0*. Semarang: Yayasan Prima Agus Teknik, 2023. [Online]. Available: https://penerbit.stekom.ac.id/index.php/yayasanpat/article/view/457

[3] V. Potočan, M. Mulej, and Z. Nedelko, “Society 5.0: balancing of Industry 4.0, economic advancement and social problems,” *Kybernetes*, vol. 50, no. 3, pp. 794–811, 2021, doi: 10.1108/K-12-2019-0858.

[4] L. Ellitan, “Competing in the Era of Industrial Revolution 4.0 and Society 5.0,” *J. Maksipreneur Manajemen, Koperasi, dan Entrep.*, vol.

10, no. 1, p. 1, 2020, doi: 10.30588/jmp.v10i1.657.
[5] I. Fitri, *Tren Evolusitik Masa Depandari Revolusi Industri 4.0 Menuju Society 5.0*. Banten: Minhaj Pustaka, 2016.
[6] N. Fitriani, "Educational Transformation in the Era of Industrial Revolution 4.0 and Society 5.0: Challenges and Solutions," *Cendekia Pendidik.*, vol. 4, no. 9, pp. 48–58, 2024, doi: doi.org/10.9644/sindoro.v4i5.3317.
[7] Badriyah, R. Mardhika, and Y. Sahria, *Media-Media Pembelajaran*. Yogyakarta: PT Penamuda Media Casa, 2023.
[8] M. Hasan *et al.*, *Media Pembelajaran*, Mei 2021., vol. 1, no. April. Klaten: Tahta Media Group, 2021.
[9] Z. Miftach, "Industrial Revolution 4.0 in Education," vol. 4, no. 6, pp. 53–54, 2021, [Online]. Available: https://jurnal.uns.ac.id/shes
[10] C. Seemiller and M. Grace, *Generation Z goes to College*. San Francisco, CA: Jossey-Bass Publisher, 2016. doi: https://doi.org/10.1080/2194587X.2017.1338583.
[11] D. T. P. Yanto, Ganefri, Sukardi, J. P. Yanto, R. Kurani, and Muslim, "Engineering Students' Acceptance of Augmented Reality Technology Integrated with E-Worksheet in The Laboratory Learning," *Int. J. online Biomed. Eng.*, vol. 20, no. 3, pp. 39–54, 2024, doi: 10.3991/ijoe.v20i03.46101.
[12] S. Ramaila and A. J. Molwele, "The Role of Technology Integration in the Development of 21st Century Skills and Competencies in Life Sciences Teaching and Learning," *Int. J. High. Educ.*, vol. 11, no. 5, p. 9, 2022, doi: 10.5430/ijhe.v11n5p9.
[13] D. P. Nilamsari and I. P. Dewi, "Rancang Bangun Media Assemblr Edu Berbasis Augmented Reality Mata Pelajaran Dasar-Dasar Teknik Elektronika," *Voteteknika (Vocational Tek. Elektron. dan Inform.*, vol. 11, no. 1, p. 96, 2023, doi: 10.24036/voteteknika.v11i1.121759.
[14] Y. Yusmaningsih, V. I. Delianti, L. Mursyida, and R. Marta, "Development of Interactive Learning Media Based on Motion Graphic Animation for Basic Photography Subject Pengembangan Media Pembelajaran Interaktif Berbasis Motion Graphic Animation," *J. Hypermedia Technol. Learn.*, vol. 2, no. 3, pp. 304–319, 2024, doi: https://doi.org/10.58536/j-hytel.v2i3.146.
[15] Z. Ardian, P. E. Arian, and R. Nuzul, "Pembuatan Aplikasi AR Geokul Sebagai Media Pembelajaran Bentuk Moelekul pada Mata Pelajaran Kimia di SMA Menggunakan Augmented Reality Berbasis Android," *J. Informatics Comput. Sci.*, vol. 7, no. 2, 2021.
[16] J. Bacca, S. Baldiris, R. Fabregat, S. Graf, and Kinshuk, "Augmented Reality Trends in Education: A Systematic Review of Research and Applications," *Int. Forum Educ. Technol. Soc. Natl. Taiwan Norm. Univ.*, vol. 17, 2014.
[17] Khoirianisa, V. I. Delianti, T. S. Wahyuni, and H. K. Saputra, "Pengembangan Media Pembelajaran Pengenalan Alat Ukur Berbasis Augmented Reality Mata Pelajaran DTJKT Di SMKN 2 Padang," *Voteteknika (Vocational Tek. Elektron. dan Inform.*, vol. 11, no. 3, p. 311, 2023, doi: 10.24036/voteteknika.v11i3.124870.
[18] Thiagarajan, Sivasailam, and Others, "Instructional development for training teachers of exceptional children: A sourcebook," *J. Sch. Psychol.*, vol. 14, no. 1, p. 194, 1974, doi: 10.1016/0022-4405(76)90066-2.
[19] W. N. Saputra and I. B. Handaka, "Analisis validitas dan reliabilitas skala perilaku agresi," *Peran Bimbing. dan Konseling dalam Penguatan Pendidik. Karakter*, no. 2001, pp. 260–268, 2021.
[20] G. Molina and Thamrin, "Pengembangan Media Pembelajaran Komponen Elektronika Berbasis Augmented Reality," *Voteteknika (Vocational Tek. Elektron. dan Inform.*, vol. 9, no. 4, p. 20, 2021, doi: 10.24036/voteteknika.v9i4.114206.
[21] I. P. Dewi *et al.*, "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, pp. 858–866, 2025, doi: 10.18178/ijiet.2025.15.4.2292.
[22] D. K. Azmi and H. Hidayat, "Design of Augmented Reality Interactive Learning Media for PISAV Subjects," *Int. J. Eng. Collab. Learn.* , pp. 25–31, 2024, [Online]. Available: https://ijecl.ppj.unp.ac.id/index.php/ijecl/article/view/57%0Ahttps://ijecl.ppj.unp.ac.id/index.php/ijecl/article/download/57/13
[23] A. Burhanudin, "Pengembangan Media Pembelajaran Augmented Reality Pada Mata Pelajaran Dasar Elektronika Di Smk Hamong Putera 2 Pakem," *Pendidik. Tek. Mekatronika*, vol. 7, no. 3, p. hlm.267, 2017.