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Integration of Virtual Reality Media in Teaching Factory to Enhance 4C Skills in Vocational Education

Aci Primartadi[1], Dwi Jatmoko[2], Yusri bin Kamin[3], Zainal Arifin[4]
[1,2]Universitas Muhammadiyah Purworejo, Purworejo, Indonesia
[3]Universiti Teknologi Malaysia, Johor Bahru, Malaysia
[4]Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

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ABSTRACT

This study aims to explore the integration of Virtual Reality (VR) technology into automotive learning based on Teaching Factory to support the development of 21st century competencies Critical Thinking, Creativity, Collaboration, and Communication (4C) in vocational high school students. A descriptive qualitative approach was used, with data collected through interviews, observations, literature reviews, and documentation analysis of teachers and students in the field of light vehicle engineering. In addition, a survey was conducted in several vocational high schools to complement the findings. The results indicate that the use of Virtual Reality enhances students' creativity and critical thinking, improves their understanding of industrial work procedures, and provides a realistic and safe learning environment. This study contributes to research on digital learning tools in vocational education by highlighting the potential of integrating Virtual Reality in a Teaching Factory setting, which is still underexplored in current practice.

INTRODUCTION

The rapid advancement of digital technology has brought significant transformation to education, including vocational education.(Delcker, J, 2022). As vocational institutions, Vocational High Schools are expected to produce graduates equipped not only with technical expertise but also with 21st century skills Critical Thinking, Creativity, Collaboration, and Communication (4C) (Keken Wulansari, 2023). To bridge the gap between education and industry, many Vocational High Schools have adopted the Teaching Factory (TEFA) learning model, which simulates a real-world industrial environment. However, the implementation of Teaching Factory faces challenges such as limited infrastructure, high operational costs, and safety concerns (Sappar, R & Zulkifli, R. M, 2024). These restrictions reduce its ability to properly develop 4C abilities, underscoring the pressing need for creative and technologically advanced teaching strategies.

In this context, Virtual Reality (VR) technology offers a promising alternative. VR enables students to engage in immersive, interactive simulations that replicate industrial procedures safely and efficiently. Studies have shown that VR-based vocational training—such as automotive painting—enhances skill acquisition through instructional designs aligned with the 4C model, integrating knowledge, skills, and attitudes. (A. Ipsita et al, 2025); (Okta Purnawirawan & Muhammad Harlanu, 2019). In Indonesia, research by (Susanto, H. M. A, 2025) developed a VR based learning model for automotive competencies, which combines skills, knowledge, and attitudes.

Despite its potential, the integration of VR into automotive TEFA remains limited due to constraints in infrastructure, teacher readiness, and curriculum alignment

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(Zhuochen Xiong, 2022). Therefore, this study examines how the use of VR in automotive Teaching Factory learning in vocational schools is successful, with a focus on improving students' 4C skills. In the context of automotive education in vocational schools, practical skills are very important skills to prepare graduates to enter the workforce (Rendra A.P. et al, 2024). However, not all vocational schools have facilities like those in the real automotive industry, such as computer-based diagnostic tools, ECU simulators, or electronic injection systems. In this case, virtual reality (VR) technology is an effective and inventive alternative (Okta Purnawirawan, I. M. S, 2019). With VR, students can see car components visually and interactively, learn how the engine works, the electrical system, and routine maintenance procedures without experiencing damage or accidents (Mohamed Elessawy et al., 2021).

Studies show that VR can improve learning efficiency in automotive education (Aci Primartadi, 2024). By using virtual media in car engine simulations in vocational schools, students can gain a better understanding of how components move, interact, and work in real time in a closed system that is difficult to access directly, according to (Lee, H, W., K, 2020). This has led to the emergence of a visual kinaesthetic learning approach, which is very suitable for vocational school students with a practical learning style. In addition, it has been proven that the adoption of VR accelerates contemporary automotive technology. With the advent of hybrid systems, electric vehicles, and Internet of Things-based systems, the automotive industry is currently increasingly digital (Dwi Jatmoko, 2023). Unfortunately, most vocational schools do not have the ability to provide the vehicles or equipment needed for this development (Zhuochen Xiong, 2022). Students can learn simulations of electric vehicles, induction motors, lithium-ion battery systems, and smart diagnostic devices through VR, even though real devices are not in the school workshop.

In vehicle learning, VR also helps teachers deliver complex materials more effectively and interestingly (Leila Mekacher, 2019). By using applications such as Automotive VR Trainer or Unreal Engine Automotive Simulator, instructors can demonstrate engine disassembly and assembly procedures, perform damage analysis, or check the electronic fuel injection ABS system without having to do it physically for a long time (Pavlekovic, M., et al, 2021). This not only saves resources but also makes learning more flexible and in accordance with students' abilities. Therefore, incorporating VR into automotive vocational schools is a strategic step for vocational education reform that is in accordance with industry 4.0 and society 5.0, not just a technology trend. This technology has the potential to be an important bridge between limited educational resources and demands for global competence with the support of government policies and industry collaboration (Airila, T., 2022).

Vocational education institutions such as vocational schools are expected to focus on technical aspects along with the development of the concept of 21st century education. Institutions are also expected to equip students with the soft skills needed for modern jobs. To face the dynamics of the rapidly changing industry, students must have the 4C skills: critical thinking, creativity, collaboration, and communication (Yeni Saufina Siregar & Siman, 2023). Automotive learning that integrates virtual reality (VR) offers an excellent opportunity to develop these four dimensions more comprehensively and contextually (Gongjin Lan, et al., 2023). Through VR based simulation scenarios, students are faced with various problem-solving situations that require critical thinking

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(Hasan Maksum, et al., 2024). For example, in a simulation of repairing an electronic fuel injection ABS system that is experiencing problems, students must analyze the symptoms of damage, choose a virtual diagnostic tool, and determine the right repair steps. This process trains them to think logically, analyze data, and make evidencebased decisions skills that are very much needed in a modern workshop environment (Y. Liu, 2023).

In addition, virtual environments help students become creative. In the ever-changing world of automotive technology, students must be accustomed to thinking outside the box and innovating (L. Long & X. Zeng, 2024). VR allows testing new maintenance procedures in a safe and secure environment, as well as programming car electronic controls and vehicle design. This provides the freedom to try new and challenging things without the worry of making potentially fatal mistakes (Lee, H, W., K, 2020). When students work together in teams in multi-user virtual reality simulations, the collaboration dimension increases. In an integrated scenario, students can work together as mechanics, electrical technicians, and workshop managers, and perform virtual vehicle diagnostics together (Mohamed Elessawy et al., 2021). This fosters a sense of teamwork, collaboration, and task allocation, which are essential skills required in industrial jobs.

Finally, students' communication skills are enhanced with VR because students can discuss diagnoses, explain research results, and provide suggestions for improvement in class discussions or online forums (Hincapié, M, 2022). In the virtual world, interactions can even include customer service simulations, teaching students how to convey technical information in a polite manner, which is a very important skill in the real world of work (Benjamin Knoke, 2021). Therefore, the integration of VR into automotive learning based on tefa learning will improve students' technical skills and produce innovative, flexible, and cooperative graduates in accordance with the requirements of industry 4.0 and society 5.0. This shows that digital transformation in vocational education is a necessity to improve the quality and competitiveness of vocational school graduates at the national and global levels (Dwi Jatmoko, 2023). While Virtual Reality has shown promise in vocational training, its application within automotive Teaching Factory settings specifically for enhancing students' 4C skills remains underexplored and under implemented. This study aims to explore how the integration of Virtual Reality media in automotive Teaching Factory learning contributes to the development of 4C skills among vocational high school students, while identifying implementation challenges and opportunities in the vocational education context.

RESEARCH METHOD

To find out how integrating virtual reality (VR) into Teaching Factory (TEFA) learning environments helps students develop their 4C skills Critical Thinking, Creativity, Collaboration, and Communication this study used a qualitative descriptive approach. The researcher was able to record participants lived experiences and contextual realities without manipulating them thanks to the qualitative descriptive approach, which offers a rich, thorough account of events in their real world settings. This study employed a descriptive qualitative approach, which is well-justified for capturing the lived experiences and contextual realities of vocational students and teachers engaged in VR-assisted Teaching Factory (TEFA) learning. Rather than focusing on numerical generalizations, the research prioritized descriptive depth to gain genuine insights into how students interact with VR-supported exercises in real educational settings. By using this method, the researcher was able to explain not only the actions that were visually apparent but also the underlying ideas, motives, and interpretations of the teachers and students who participated in the teaching and learning process.(Yeni Saufina Siregar & Siman, 2023).

The research was conducted at two vocational high schools located in Central Java, Indonesia: SMK Muhammadiyah Purwodadi and SMK Negeri 8 Purworejo. Both institutions offer the Light Vehicle Engineering program and have adopted the Teaching Factory model as part of their industrial based curriculum. These schools were purposefully selected due to their active integration of Virtual Reality as an instructional tool in automotive workshop learning. Participants included four vocational subject teachers (two from each school) who specialize in automotive maintenance and diagnostics, along with 20 Grade XI students who were purposively chosen for their active participation in VR-assisted TEFA activities. This purposive sampling ensured that all participants had direct and meaningful experience with the phenomenon under study, enhancing the relevance and richness of the data collected.

The following is a Data Analysis of the Implementation of the Automotive Teaching Factory Based on Virtual Reality to Strengthen 4C Skills in Vocational Student (Bakkiyaraj M. et al, 2022):

1. Data Sources and Collection Techniques

Data were collected using multiple techniques to ensure a comprehensive understanding of the phenomenon. First, classroom observations were conducted during teaching and learning sessions that involved VR simulations in automotive practical workshops. These observations focused on how students engaged with VR tools to solve problems, communicate, and collaborate within the Teaching Factory context. Second, in depth semi structured interviews were carried out with both teachers and students. These interviews allowed participants to reflect on their experiences and share personal insights regarding the impact of VR use on their 4C skill development. Third, documentation such as lesson plans, student assignments, practicum reports, photographs, and presentation videos was collected to provide contextual and triangulated evidence. Lastly, a literature review of relevant scholarly works helped to support and validate the empirical findings.(Amat Jaedun, et al., 2024).

The main focus is to improve students' 4C skills through the use of virtual reality (VR) technology in factory teaching. From interviews with teachers, it was found that the use of VR in vehicle maintenance simulations improved students' understanding of technical procedures and improved students' critical and creative thinking skills (Bachri, S. et al., 2024). Meanwhile, observation notes showed that students worked better together when using virtual reality. This is because this process systematically filters data, so that researchers can only analyze elements related to how effective the contextual learning of the virtual learning factory.

2. Data Analysis Procedures

Data analysis followed the model, which includes three interconnected activities: data reduction, data display, and conclusion verification. In the data reduction stage,

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raw data from interviews, observations, and documentation were filtered, selected, and condensed to focus on meaningful patterns related to 4C skill development. Redundant or irrelevant information was excluded to maintain clarity and focus.

In the data display stage, reduced data were organized into visual and narrative forms, including coding tables, matrices, and thematic descriptions. These displays allowed the researcher to draw clear comparisons and interpretations of the data. Finally, in the conclusion drawing and verification stage, recurring themes were identified and interpreted to construct meaningful insights. Verification was achieved through triangulation and continuous cross-checking across data sources. (Moro, C, et al., 2022).

Table 1 shows that student data prefer to work together with VR for vehicle electrical system repair simulations because they share tasks and talk to each other about how to complete the task. The data show that VR encourages student engagement in discussions because the visualization of work procedures becomes clearer and more concrete (Ahmad Aris, 2022). In addition, teachers reported that because students need to collaborate to express opinions and find technical solutions, communication between them becomes more active. The data presented here shows how technology is used in teaching factory learning to support collaboration and communication skills, which are key pillars of competence in this century (Efendi, Y & Yanti, R., 2024).

3. Coding Process and Data Trustworthiness

The coding process began with open coding, where initial themes were manually extracted from interview transcripts and observation notes. Codes were assigned to expressions or behaviors indicating 4C related competencies, such as technical problem solving for critical thinking or peer explanation for communication. This process enabled the emergence of detailed and grounded categories directly from the participants voices.

Following open coding, axial coding was used to relate and group these initial codes under broader categories aligned with the 4C framework. Themes such as technical diagnostics (critical thinking), design innovation (creativity), team collaboration, and verbal articulation (communication) were developed. These codes were then further refined through thematic grouping to represent interrelated skill domains observed during the VR based Teaching Factory activities. (Tri Kuat, et al., 2023). Students' critical thinking skills are seen from their ability to analyze technical problems simulated in virtual space, such as diagnosing electronic fuel injection damage. Students also become creative when given the challenge of designing technical solutions for vehicle systems simulated in virtual space. When students work together, collaboration appears strong.

4. Trustworthiness Measures

To ensure the credibility and reliability of the findings, several strategies were employed. Triangulation was conducted by comparing data from different sources interviews, observations, and documents to verify consistency and reduce the possibility of researcher bias. This methodological triangulation provided a more nuanced and robust understanding of the research problem. In addition, member checking was applied by sharing the interpreted data with participants to confirm the accuracy of the findings. Participants were given opportunities to validate or clarify

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statements they had made. Furthermore, peer debriefing was conducted by discussing coding and thematic interpretations with fellow researchers. This helped refine the accuracy of the codes and increased the trustworthiness of the conclusions.

5. Ethical Considerations

This research adhered to ethical standards by securing informed consent from all participants. For student participants under the age of 18, parental or guardian consent was also obtained. The consent process included explanations about the research purpose, data use, and the voluntary nature of participation. Participants were assured of their right to withdraw at any stage without any negative consequences. To maintain ethical integrity, all data were anonymized to ensure participant confidentiality. Pseudonyms or codes were used in the reporting of data to protect identities. The data were stored securely and used solely for academic purposes. Throughout the research process, the principles of respect, honesty, and responsibility were upheld in alignment with ethical research practices.

By combining consistent interview results, observations, and documentation, verification is carried out to show that tefa-based learning using Virtual Reality:

Table 1. Data analysis of the implementation of VR based automotive Teaching Factory to improve 4C

No	Aspect 4C	Indicator Interview	Results/ Findings	Documentation Evidence	Interpretation
1	Critical	Ability to diagnose vehicles with simulation	Students are able to simulate vehicles to diagnose damage to electronic fuel injection systems through VR.	Transcript of student discussion when analyzing electronic fuel injection system	VR enhances analytical power in depth
2	Creative	Designing alternative solutions to the management problems created	Students propose modifications to the electronic fuel injection system to make it more efficient.	Observation notes and student reports from the practicum report	VR stimulates creativity through problem visualization
3	Collaboration	Students collaborate on project based assignments	In groups, students share roles when completing an electronic fuel injection repair simulation	Documentation image of collaborative practice activities	Teaching Factory encourages real-world work collaboration in VR simulations
4	Communication	Students communicate technical ideas clearly	Students present the results of damage analysis with strong technical arguments.	Student group presentation video	Communicatio n evolves in explaining technical solutions in discussion forums

RESULTS AND DISCUSSION

Results

The results clearly demonstrate how the integration of Virtual Reality (VR) in the automotive Teaching Factory enhances students 4C skills Critical Thinking, Creativity, Collaboration, and Communication. VR based simulations, such as vehicle maintenance

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procedures, component replacement, and system diagnostics, offer students immersive and interactive experiences that closely mirror real industrial tasks (Zhuochen Xiong, 2022). Teachers use virtual reality devices to start industrial tasks repeatedly. In some aspects, students improve. Students improve in analyzing damage and determining repair steps (critical), creating creative solutions for unusual damage (creative), working together in teams to complete repair simulations (collaboration), and actively talking with teachers and students about work steps. The results of interviews with twenty students and four productive teachers from SMK Muhammadiyah Purwodadi and SMK Negeri 8 Purworejo showed that the use of virtual reality-based Teaching Factory helps students improve their 4C skills. Both teachers and students said that Teaching Factory technology can make real-life simulations more interesting and meaningful than conventional methods

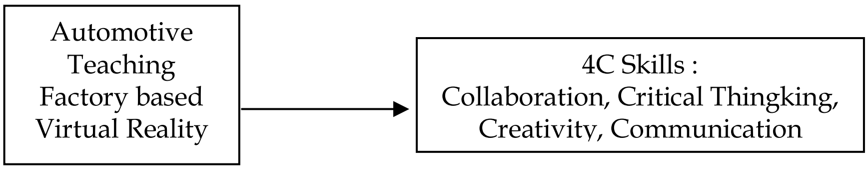

Figure 1. Stages of Tefa Learning Integrated with VR

In terms of Critical Thinking, the four teachers said that students who use VR in vehicle maintenance tasks understand the technical workflow faster and are better trained in analyzing damage. In the injection system simulation, students are able to identify sensor damage and make logical decisions without having to dismantle the vehicle directly, said a teacher at SMK Negeri 8 Purworejo.

The integration of Virtual Reality (VR) in automotive Teaching Factory (TEFA) learning has a significant impact on the development of students' 21st century skills, especially in the aspects of Critical Thinking, Creativity, Collaboration, and Communication.

1. Critical Thinking

Four productive teachers from SMK Muhammadiyah Purwodadi and SMK Negeri 8 Purworejo reported that the use of VR in vehicle maintenance simulations, such as injection systems and cooling systems, helped students understand technical workflows more quickly and accurately. One teacher stated:

> "*In the injection system simulation, students can immediately analyze which sensors are problematic and determine repair steps without having to physically disassemble the vehicle*." (Teacher, SMK Negeri 8 Purworejo)

Students' ability to analyze damage and make logical decisions increases because they face engine damage scenarios systematically through repeated simulations. This strengthens the formation of critical thinking patterns based on direct experience.

2. Creativity

The use of VR also triggers students to create creative solutions. Some students began to develop their own technical ideas after getting used to using VR simulations. A student from SMK Muhammadiyah Purwodadi said:

> "*I started to think about making a more efficient injection system after seeing the diagnostic flow in VR*." (Student, SMK Muhammadiyah Purwodadi)

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Two teachers also observed that students did not only repeat procedural steps, but began to modify the simulation scenario and suggest alternative solutions, which previously did not appear during conventional learning.

3. Collaboration

Most students stated that they felt more active in working together when completing project-based assignments in the VR environment. One student said:

> *"We studied for the assignment together, some took notes, some observed, and some tried out the solutions directly in the simulation."* (Student, SMK Negeri 8 Purworejo)

The teacher confirmed that the group dynamics became more lively, because each group member had a balanced active role. VR-based projects encouraged intense interaction, in-depth technical discussions, and effective role-sharing.

4. Communication

According to teachers, VR helps students convey technical ideas more coherently and convincingly, especially when presenting discussion results. Clear visualizations in VR make it easier for students to understand how a vehicle works, so they are more confident when explaining concepts:

> *"Children who are usually passive, when using VR become active in speaking and can explain how the system works because they see it directly visually."*
> (Teacher, SMK Muhammadiyah Purwodadi)

Improvements in technical communication skills were also seen when students discussed improvement steps and put forward arguments based on the results of the simulations that students went through directly.

Table 2. Summary of Findings Based on the 4C Framework

Aspect 4C	Key Findings	Source Quotes
Critical Thinking	Students are able to analyze damage and determine repair steps more systematically	"...immediately analyze which sensor is problematic..." (Teacher, SMK N 8 Purworejo)
Creativity	Students develop new technical solutions after simulation exploration	"...thought of making a more efficient injection system..." (Student, Muhammadiyah Purwodadi Vocational School)
Collaboration	Collaboration increases because each group member has an active role in the VR simulation	"...together, some take notes, observe, try out solutions..." (Student, SMK N 8 Purworejo)
Communication	Students are more confident in conveying ideas because of VR visual-based understanding	"...so they can actively speak and explain how the system works..." (Teacher, Muhammadiyah Purwodadi Vocational School)

Teachers saw an improvement in students' ability to convey concepts technically and coherently, especially when they showed the results of the simulation. Teachers said that students were able to explain the results of group discussions because students understood VR visually and realistically, "children who are usually quiet, when practicing VR are actively explaining how the system works because students see it

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visually and realistically." This shows that VR can naturally help students acquire technical communication skills. Overall, the interview results showed that both teachers and students really liked the integration of virtual reality into the educational factory. This technology not only enhances automotive learning, but can also make students more flexible, innovative, and creative (Suyitno et al., 2023). This is in line with the current vocational education policy which emphasizes the integration of technology and soft skills to prepare students for the world of work 4.0.

Discussion

The use of Virtual Reality (VR) in Teaching Factory (Tefa) learning has shown great potential in strengthening 21st-century skills, especially the 4C dimensions (Critical Thinking, Creativity, Collaboration, and Communication). The results of this study confirm that the VR-based approach is able to provide a learning experience that resembles the real industrial world (Urbani, C., 2020), in line with the contextual learning approach emphasized in modern vocational education. Theoretically, VR based learning supports constructivist theory, where students build knowledge through authentic experiences and active interactions with the virtual environment. For example, in the Critical Thinking aspect, students are able to transmit vehicle damage through injection system simulations without physically dismantling components. This not only accelerates the understanding of technical workflows but also trains logistical skills in the decision-making process. This is in line with the constructivist view that direct experience strengthens high-level thinking processes.

In the Creativity aspect, VR provides an imaginative space that allows students to design alternative technical solutions to complex simulated problems. This is consistent with the findings of (Putra, A. W & Sugiarto, B, 2021), that the use of VR in educational techniques encourages the formation of creative ideas through media transmission and interactivity. For example, the emergence of students' ideas to design a more efficient fuel injection system is a concrete form of creative thinking stimulated by the VR simulation experience.

From the perspective of Vygotsky's sociocultural theory, collaborative learning in VR simulations creates a zone of proximal development, where students learn from each other through group work. VR based projects encourage equal role-sharing and effective communication between team members, creating strong and supportive group dynamics. This shows that the collaboration that occurs in VR based Teaching Factory not only develops technical skills, but also internalizes the values of teamwork that are essential in the real world of work.

Furthermore, the Communication aspect develops naturally through visual and immersive learning experiences. Students become more confident in conveying technical analysis because they understand the work process thoroughly through visual simulations. This experience shows that technology is not only a visualization tool, but also strengthens technical communication skills as part of the soft skills that are very much needed in the modern work environment.

However, VR learning in Tefa also has challenges, especially related to limited infrastructure and teacher readiness. The availability of adequate devices and ongoing teacher training are still major obstacles to large-scale implementation. For this reason, practical recommendations are needed, including:

1) Strategic partnership with industry for the gradual provision of VR devices.

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2) Development of continuous training modules for teachers to have technopedagogical competence in optimally utilizing VR.
3) Integration of project-based learning with a VR approach as part of a flexible national curriculum.

Overall, the integration of VR in Teaching Factory learning not only improves students' technical skills, but also strengthens cognitive and social aspects in the vocational learning process. This is in line with the goal of 21st century vocational education to build adaptive, creative, and competitive human resources in the era of the Industrial Revolution 4.0 (L. Long & X. Zeng, 2024). Therefore, Teaching Factory is not only a production-based pedagogical approach, but also a transformational strategy to produce tough and innovative vocational graduates.

CONCLUSION

The findings of this study clearly highlight that the integration of Virtual Reality (VR) into Teaching Factory based instruction in automotive engineering significantly supports the development of 21^{st} century competencies among vocational high school students. Specifically, VR-assisted learning environments enhance students communication, collaboration, creativity, and critical thinking by providing immersive, interactive, and risk free opportunities to engage with complex industrial tasks. These results underscore the value of incorporating VR as a pedagogical tool to strengthen 4C skills, making vocational education more responsive to the evolving demands of the modern workforce. Virtual reality provides an immersive and contextual simulation environment that allows students to engage in diagnostic activities, explore innovative solutions, and interact with complex systems without the need to disassemble actual vehicles. This fosters not only technical understanding but also teamwork and effective communication, aligning well with the collaborative and problem solving nature of real-world industrial settings.

The implementation of a virtual reality based teaching factory represents an innovative and promising approach to vocational education. It offers a low risk, engaging, and industry-relevant learning experience that bridges the gap between traditional instructional models and the technological demands of Industry 4.0. Through this paradigm, vocational schools can better prepare students for workforce readiness in dynamic and technology-driven environments that require flexibility, technical literacy, and strong interpersonal skills.

Nevertheless, this study has several limitations. It employed a qualitative approach with a limited number of participating instructors and schools, which may constrain the generalizability of the findings. Additionally, challenges related to the adoption of VR technology such as infrastructure readiness, teacher training, and funding were acknowledged but not explored in depth. Future research should incorporate larger-scale empirical studies using quantitative methods to validate the impact of VR-based teaching factory instruction on student learning outcomes. Comparative studies across different disciplines or geographical contexts, as well as investigations into teacher preparedness and cost-effectiveness, would also contribute to a deeper understanding of the scalability and sustainability of this pedagogical model.

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REFERENCES

Aci Primartadi, et al. (2024). Development of Learning Media for Motorcycle Technology Clutch Systems in Higher Education. Jurnal Taman Vokasi, 9(2). https://doi.org/10.30738/jtvok.v9i2.11504

Ahmad Aris, D. J. (2022). Development of Audio Visual Learning Media Scanner Motor Type MASTER MST 100p to Improve Learning Interest of Class XI TBSM Students at SMK PN2 Purworejo.13(4). Autotech: Jurnal Pendidikan Teknik Otomotif UMPurworejo, 17(1). https://doi.org/10.37729/autotech.v17i1.

A. Ipsita et al. (2025). Virtual Reality in Manufacturing Education: A Scoping Review Indicating State of the Art, Benefits, and Challenges. 2(3)

Airila, T., et al. (2022). Promoting workplace guidance and workplace–school collaboration in vocational training: A mixed-methods pilot study. Vocations and Learning, 15(2), 143–162. https://doi.org/10.1007/s12186-022-09289-5

Amat Jaedun, et al. (2024). Perceptions of Vocational School Students and Teachers Regarding the Integration of Interpersonal Skills into the Curriculum. 9(3) Jurnal: Cogent Education, 11(1). https://doi.org/10.1080/2331186X.2024.2375184

Bachri, S. et al. (2024). Enhancing student engagement in vocational education by using virtual reality. Multidisciplinary Science Journal. https://doi.org/10.1007/s10055-018-0363-2

Bakkiyaraj M. et al. (2022). Effectiveness of training method using virtual reality and augmented reality applications in automobile engine assembly. ASEAN Engineering Journal, 12(4), 83–88. https://doi.org/10.11113/aej.v12.18009

Benjamin Knoke. (2021). Training simulators for manufacturing processes: Literature review and systematisation of applicability factors. 14(2) Computer Applications in Engineering Education. https://doi.org/10.1002/cae.

Delcker, J, I., D. (2022). Digital distance learning and the transformation of vocational schools from a qualitative perspective. Frontiers in Education, 7(2). https://doi.org/10.3389/feduc.2022.908046

Dwi Jatmoko, et al. (2023). The Factors Influencing Digital Literacy Practice in Vocational Education: A Structural Equation Modeling Approach. 4(3) European Journal of Educational Research, 12(2).

Efendi, Y, N., T., & Yanti, R. (2024). Virtual Reality Workshop for Teachers to Improve Learning Innovation at Muhammadiyah 2 Vocational School, Pekanbaru. Community Education Engagement Journal, 5(1). https://doi.org/10.25299/ceej.v5i1.14185

Gongjin Lan, et al. (2023). A Virtual Reality Training System for Automotive Engines Assembly and Disassembly. International Journal of Automotive Technology, 4(2), 123–136. https://doi.org/10.48550/arXiv.2311.02108

Hasan Maksum, et al. (2024). Improving Problem-Solving and Communication Skills in Automotive Vocational Education through the Development of Teaching Factory Model with Problem-Based Learning (TEFA-PBL) Concept. Jurnal: International Journal of Education in Mathematics, Science and Technology (IJEMST), 12(2). https://doi.org/10.46328/ijemst.3941

Hincapié, M, et al. (2022). Virtual Reality in Vocational Training: A Case Study in Automotive Education. Journal Education and Information Technologies, 27(3), 1919–1938. https://doi.org/10.1007/s10639-021-10665-1

Keken Wulansari, Y. S. (2023). Keterampilan 4C (Critical Thinking, Creativity, Communication, dan Collaborative) Guru Bahasa Indonesia SMA dalam Pembelajaran Abad 21 di Era Industri 4.0. Jurnal Basicedu, 7(3), 1667–1674. https://doi.org/10.31004/basicedu.v7i3.5360

Lee, H, W., K. (2020). Enhancing Engagement and Learning in Automotive Engineering with VR Simulations. Journal of Technical Education and Training, 12(2), 50–64. https://doi.org/10.30880/jtet.2020.12.02.006

Leila Mekacher. (2019). Augmented Reality (AR) and Virtual Reality (VR): The future of interactive vocational education and training for people with handicap. PUPIL: International Journal of Teaching, Education and Learning, 3(1), 118–129. https://doi.org/10.20319/pijtel.2019.31.118129

L. Long, X. Z., & X. Zeng. (2024). Application and Effect Analysis of Virtual Reality Technology in Vocational Education Practical Training. Education and Information Technologies, 30(2), 9755–9786. https://doi.org/10.1007/s10639-024-13197-7

Mohamed Elessawy et al. (2021). Evaluation of laparoscopic virtual reality training on the improvement of trainees' surgical skills. Medicina. 13(5) https://doi.org/10.3390/medicina570302

Moro, C, et al. (2022). Immersive Technology and Skill Development in Vocational Education: A Systematic Review. British Journal of Educational Technology, 53(4), 887–905. https://doi.org/10.1111/bjet.13167

Okta Purnawirawan, I. M. S., & Muhammad Harlanu. (2019). Assessment of 4C Softskills Characteristics in Learning Productive Graphic Design Subject for Vocational School. Journal of Vocational and Career Education (JVCE), 4(1), 53–60. https://doi.org/10.15294/jvce.v4i1.21867

Pavlekovic, M., et al. (2021). VR-based Learning in Mechatronics and Automotive Education. International. Journal of Engineering Pedagogy, 11(1), 57–69. https://doi.org/10.3991/ijep.v11i1.20456

Putra, A. W, P., H. Y., & Sugiarto, B. (2021). Design of Assessment Through Problem Solving Task to Support 4C Skills in Vocational Education. Journal of Technical Education and Training, 13(2), 45–54.

Rendra A.P. et al. (2024). Development of the Automotive Technology Vocational Education Curriculum Based on Current Needs of the Automotive Industry. Jurnal Pendidikan Vokasi Otomotif, 6(2). https://doi.org/10.21831/jpvo.v6i2.73156

Sappar, R, H., M. A. M., & Zulkifli, R. M. (2024). The implementation of collaborative industry practices in Malaysian vocational colleges. International Journal of Academic Research in Progressive Education and Development. International Journal of Academic Research in Progressive Education and Development, 13(2), 135–142. https://doi.org/10.6007/IJARPED/v13-i2/21140

Susanto, H. M. A. (2025). Learning to Improve 4C Competencies (Communication, Collaboration, Critical Thinking and Creative Thinking) to Welcome the 21st Century Era. Jurnal Inspirasi Mengabdi Untuk Negeri, 4(1), 231–242. https://doi.org/10.58192/sejahtera.v4i1.3028

Suyitno, S., Jatmoko, D., Primartadi, A., & Ab-Latif, Z. (2023). Industrial practice platform based on work-based learning: A solution to improve student

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 6, No. 4, July 2025
Page 1124-1135

competence. Jurnal Pendidikan Vokasi, 13(1), 98–106. https://doi.org/10.21831/jpv.v13i1.54589

Tri Kuat, et al. (2023). Edupreneurship through Teaching Factory in the Light Vehicle Engineering Skills Program at Muhammadiyah Kutowinangun Vocational School. Journal of Vocational Education Studies, 6(2). https://doi.org/10.12928/joves.v6i2.9454

Urbani, C. (2020). Teacher continuing professional development and team-working competences: A case study from Italy. Nternational Journal for Research in Vocational Education and Training, 7(2), 237–255. https://doi.org/10.13152/IJRVET.7.2.6

Yeni Saufina Siregar, E. D., & Siman. (2023). Increasing the Competence of Vocational Education Teachers with 4C Skills-Based Training Management (Critical Thinking, Creativity, Communication, Collaboration). 3(4) EAI. https://eudl.eu/doi/10.4108/eai.19-9-2023.2340493

Y. Liu, et al. (2023). A Systematic Review of VR/AR Applications in Vocational Education: Models, Affects, and Performances. Interactive Learning Environments. 11(2) https://doi.org/10.1080/10494820.2023.2263043

Zhuochen Xiong. (2022). Development of VR Teaching System for Engine Dis-assembly. Computer Science Human Computer Interaction. 8(1) https://doi.org/10.48550/arXiv.2207.05265

***Aci Primartadi (Corresponding Author)**
Department of Automotive Enginering Education,
Muhammadiyah University of Purworejo,
Jl. K. H. A, Dahlan No 3 Purworejo Central Java, 54111, Indonesia
Email: aci@umpwr.ac.id

Dwi Jatmoko
Department of Automotive Enginering Education,
Muhammadiyah University of Purworejo,
Jl. K. H. A, Dahlan No 3 Purworejo Central Java, 54111, Indonesia
Email: dwijatmoko@umpwr.ac.id

Yusri bin Kamin
Department of Technical and Engineering Education
School of Education, Faculty of Social Sciences and Humanities
Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johore, Malaysia
Email: p-yusri@utm.my

Zainal Arifin
Automotive Engineering Education Study Program, Faculty of Engineering
Universitas Negeri Yogyakarta
Jl. Colombo No.1, Karang Malang, Caturtunggal, Kec. Depok, Kabupaten Sleman,
Daerah Istimewa Yogyakarta 55281
Email: zainal_arifin@uny.ac.id