

Mixed Reality System for Automotive Vocational School: Academic Performance and Experience Assessment

Satrio Pradono Suryodiningrat*

School of Computing and Creative Arts, University of Bina Nusantara, Jakarta, Indonesia

Harjanto Prabowo

Department of Computer Science, Doctor of Computer Science, BINUS Graduate Program, Bina Nusantara University, Jakarta, Indonesia

Arief Ramadhan

School of Computing, Telkom University, Bandung, Indonesia

Harry Budi Santoso

Faculty of Computer Science, Universitas Indonesia, Depok, Indonesia

Abstract

Mixed reality (MR) devices, such as Microsoft HoloLens, offer immersive and interactive learning opportunities that can enhance vocational education. While MR technologies are increasingly used in K–12 settings, their application in vocational schools remains limited, despite the potential to improve workplace readiness of graduates in alignment with Industry 5.0 standards. This study investigates the effectiveness of MR in automotive vocational schools using a quasi-experimental pre-test/post-test design to measure student performance and a SPRADO assessment tool to assess user experience. The study involved 42 students and 9 teachers from 4 vocational high schools (from grades 9 and 10) divided into MR and non-MR groups. Academic performance was assessed through standardized pre- and post-tests, and the MR group also completed a survey using the SPRADO assessment tool, which evaluates six dimensions of MR learning systems: usability, system functionality, pedagogical alignment, realism, accessibility, and user satisfaction. The findings show a significant improvement in academic performance among students in the MR group compared to the non-MR group and revealed positive perceptions from both students and teachers in the MR group regarding the capabilities of MR in supporting learning. These results provide empirical support for integrating MR into vocational curricula as a strategic response to evolving technological and industrial demands.

Keywords: SPRADO assessment tool, mixed reality, quasi-experimental design, vocational education

Suryodiningrat, S. P., Prabowo, H., Ramadhan, A., & Santoso, H.B. (2026). Mixed reality system for automotive vocational school: Academic performance and experience assessment, *Online Learning*, 30(1), pp. 246-264. <https://doi.org/10.24059/olj.v30i1.4805>

In recent years, there have been significant improvements in mixed reality (MR) technology, resulting in the creation of a hybrid environment that seamlessly combines the physical and digital worlds. These systems utilize state-of-the-art technology, including advanced sensors, real-time 3D visualization, spatial mapping, and AI-driven interactions to offer immersive experiences that surpass the capabilities of standard virtual reality and augmented reality (Morimoto et al., 2022). Devices such as Microsoft HoloLens 2 and Magic Leap One demonstrate the advancements in MR hardware, allowing users to view and engage with digital content that is overlaid with the physical world. These systems utilize advanced cameras and sensors to comprehend the physical surroundings, enabling holograms to be precisely integrated into the real world (Maas & Hughes, 2020).

Education is being transformed by MR, as it allows students to engage with 3D models of intricate architecture, historical landmarks, and scientific processes, thereby making abstract ideas more tangible and captivating. Within the healthcare field, the utilization of MR technology is revolutionizing both medical training and practice (Sievers et al., 2020). In engineering education, MR enhances learners' ability to visualize systems, diagnose problems, and test solutions in simulated settings (Rokhsaritalemi et al., 2020). These examples reflect MR's growing role in bridging theoretical instruction with real world application. The potential of MR in the future offers the possibility of a more profound integration into our everyday lives, fundamentally transforming our interactions with technology, other individuals, and the physical environment (Pellas et al., 2020).

Despite its promise, MR remains underutilized in vocational education. Compared to K-12 schools, which increasingly adopt MR to enhance learning in subjects like Physics, History, and Mathematics, vocational schools have been slower to integrate this technology (Suryodiningrat et al., 2023). This disparity can be attributed to several factors, including limited funding, reliance on conventional teaching methods, and a lack of teacher preparation or familiarity with emerging technologies (Béduwé & Giret, 2011; Heaviside et al., 2018; Jaya et al., 2020). As a result, vocational students often miss out on the immersive and practical experiences that MR can offer. This is particularly concerning in automotive vocational schools where students must develop both conceptual knowledge and hands-on skills. Many graduates of these schools encounter considerable difficulties while transitioning into the job world, as a large number of them fail to fulfill the industry's requisite competency standards and are insufficiently equipped to become fully prepared professionals (Durmus & Dağlı, 2017; Suharno et al., 2020). As a result, graduates may encounter difficulties in effectively operating, maintaining, and resolving issues with modern equipment, which might result in a significant learning challenge when they start working. Employers often face the need to allocate time and resources to provide additional training for new personnel, which can impede production and efficiency. Furthermore, the lack of alignment between academic preparation and industrial requirements can lead to decreased self-assurance and job contentment among graduates, which can harm their overall professional growth and advancement (Heaviside et al., 2018; Imam Agung et al., 2018).

Integrating MR into vocational education offers a promising solution. MR can revolutionize vocational training by providing immersive and interactive teaching environments that seamlessly integrate academic knowledge with practical applications (Smith et al., 2021). Through technologies such as holograms, real-time 3D visualization, and interactive simulations,

students can safely practice tasks like disassembly, troubleshooting, and machine operations (Boel et al., 2023). MR also facilitates collaborative learning by allowing teachers to offer immediate advice and feedback from a distance, overcoming geographical limitations, and making education more accessible to a wider range of people (Wang & Li, 2024). In addition, MR can accurately reproduce real-life situations, thereby equipping students with the necessary skills and experience to tackle the obstacles they may encounter in professional settings (Ogunseiju et al., 2022). By incorporating MR into the curriculum, vocational schools can produce more confident, workforce-ready graduates who are better equipped for modern industrial demands.

Despite these advantages, empirical research on MR in vocational education, particularly in the automotive sector, remains limited. To address this gap, this study used a quasi-experimental design to investigate how MR could improve student performance in four automotive vocational schools in Indonesia. The study also looked at user experience. By combining test results and user impressions, the study gives a full view of how MR can support vocational education and help prepare students for modern industry needs.

Literature Review

Given the promise of MR to provide immersive environments that connect theoretical learning with practical application, several studies have explored its impact across diverse training contexts. For example, Adams et al. (2022) investigated the use of MR with the Microsoft HoloLens 2 in vocational education, namely in nursing curricula. The findings emphasize MR's capacity to improve spatial reasoning and situational judgment, allowing learners to engage thoroughly with course material. At the same time, this study identifies technical barriers, including interaction with college networks and user authentication difficulties, that must be resolved for wider implementation. Notably, the authors emphasize the significance of culturally responsive approaches, integrating Tikanga Māori to match MR applications with New Zealand's educational principles, especially in nursing programs where adherence to cultural conventions is crucial. This study underscores how MR can enhance vocational training when thoughtfully contextualized.

Another study, Smith et al. (2021), investigated the use of MR in vocational training for electrical technicians. This study was a comparative analysis between novices and experienced individuals performing the same task. In the study, novices used a mobile MR application to complete a fault diagnosis task on a three-phase power supply, while experienced individuals (i.e., those with prior relevant knowledge or field experience) completed the same task without the MR application. The study demonstrated that novice users utilizing the MR guidance outperformed the experienced group, suggesting that MR can supplement traditional training models by simulating practical tasks and work contexts.

While prior studies demonstrate the promise of MR in enhancing vocational training across various fields—particularly in nursing and electrical engineering—there remains a noticeable lack of empirical research focused on its application in automotive vocational education. Given the significant skills gap faced by graduates and the low adoption rate of MR in vocational schools (Suryodiningrat et al., 2023), further investigation is needed to explore how

MR can impact both academic performance and user experience in this context. Therefore, this study aims to evaluate the effectiveness of MR systems in improving learning outcomes and student engagement in automotive vocational schools in Indonesia. Using a quasi-experimental design and the SPRADO assessment tool, the study seeks to answer:

1. Does the use of MR improve students' academic performance in automotive vocational training?
2. How do students and teachers perceive the usability and educational value of MR through the SPRADO assessment tool?

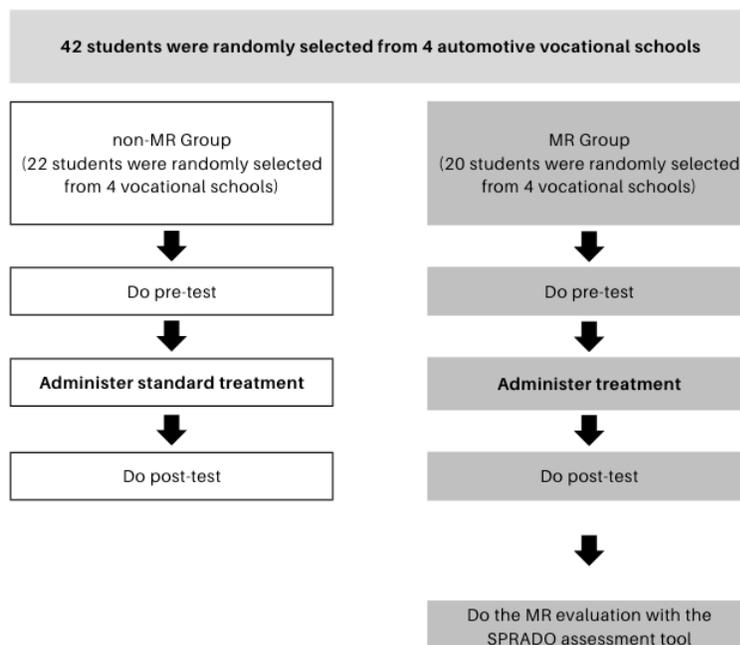
Methodology

Participants and Context of the Study

Four vocational schools for grades 10-12 in Indonesia provided the context for the study. Two groups were established: the MR group and the non-MR group. Initially, each group consisted of five grade 10 students from each school. One vocational school later contributed two additional students to the non-MR group. This brought the total number of participants to 42 students: 22 in the non-MR group, and 20 in the MR group. The objective of this study was to determine whether instruction using MR could improve students' performance. (The overall quasi-experimental design with a pre-test/post-test design is illustrated in Figure 1). In addition to the student participants, nine teachers from the MR group also engaged in the study to contribute insights on the MR's effectiveness.

Figure 1

Methodology



Data Collection Procedures

Once all the students had been assigned to their respective groups, the study began with both groups completing an identical pre-test, which consisted of 15 questions (10 multiple-choice and 5 short-answer questions). These questions were developed by a team of teachers from the four vocational schools.

Following the execution of the pre-test, the MR group engaged in an interactive learning experience using MR technology. With the Microsoft HoloLens, students explored 3D models of motorcycle engine parts, specifically from the Yamaha YZR Superbike. This allowed them to view, rotate, and examine individual components in detail to better understand their structure and function. The content focused on an introductory lesson covering the names, positions, and roles of various engine components. Before beginning the lesson, students received guidance on how to operate the MR device, enabling them to navigate the experience independently. The MR-based learning was conducted over two sessions, lasting a total of approximately 100 minutes, and emphasized exploratory learning, allowing students to interact freely with the materials and proceed at their own pace.

Meanwhile, the non-MR group learned the same content using a conventional teaching method. These students received instruction through a PowerPoint presentation delivered by the teacher, following a more traditional, lecture-based format without any immersive or interactive technologies.

After completing their respective learning sessions, both groups took a post-test using identical questions designed to assess students' understanding of the material they had learned. In addition, the students and teachers from the MR group completed a user experience evaluation using the SPRADO assessment tool, which is a specialized survey instrument designed to evaluate MR systems, focusing on teaching performance for educators and learning experiences for students (Suryodiningrat et al., 2024). This tool assesses MR across six key areas: usability, system functionality, pedagogical alignment, realism, accessibility, and user satisfaction. It applies a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree) to closed-ended questions and also includes open-ended questions to gather deeper insights.

Data Analysis

A paired-sample *t*-test was conducted with each group's pre- and post-test scores to determine whether the difference in scores was statistically significant. The resulting mean deltas between pre- and post-tests were then compared across groups using an independent-sample *t*-test to assess intergroup differences in learning gains.

The SPRADO assessment tool was used to evaluate user experience and perception, and its internal consistency was assessed using Cronbach's alpha. A significance level of $p < 0.01$ was selected for all statistical tests to ensure a high level of confidence in the results while maintaining reasonable sensitivity to detect real effects in a small sample size ($n < 50$). The 1% threshold thus provides a balanced trade-off between statistical rigor and practical feasibility in small-sample educational research.

Results and Discussion

Pre- and Post-Test Findings

Results from the pre-test and post-test scores for both the MR and non-MR groups are presented below. Full score distributions can be seen in Table 1.

In the non-MR group, the average score of the group increased from 50.00 in the pre-test to 59.77 in the post-test. Some students made notable progress. For instance, Participant 1 improved from 60 to 70, Participant 2 went from 50 to 70, and Participant 10 showed a significant gain, increasing from 35 to 100. These improvements suggest that traditional classroom learning worked well for certain individuals. However, the results were not consistent for all students. A few participants experienced a drop in their scores. Participant 9's score fell sharply from 95 to 30, and Participant 13 decreased from 55 to 20. These declines indicate that traditional methods might not have supported these students effectively or that other factors affected their learning outcomes. Some participants showed no change. For example, Participant 8 scored 50 on both tests, and Participant 19 scored 55 on both. This suggests that their performance remained stable, with little to no impact from the learning activities. Overall, the non-MR group showed a mix of improvements, declines, and stable results, reflecting the varied effectiveness of traditional instruction across different students. This observation aligns with findings from previous research, which also reported mixed outcomes in non-immersive learning environments (Moon et al., 2024; Tang et al., 2020).

Compared to the non-MR group, the MR group demonstrated notable improvements in performance. The average score of the group rose from 38.25 in the pre-test to 72.75 in the post-test. This significant increase suggests that the intervention was generally successful in improving the participants' performance. A significant number of participants demonstrated remarkable enhancements in their scores. For instance, Participants 1 through 4 improved their scores, from 50, 80, 50, and 50 in the pre-test to a 100 in the post-test, and participants 18 and 19 increased their scores from 15 in the pre-test to 100 in the post-test. Moderate improvements were also observed, such as Participant 5's score increased from 45 to 90, Participant 7's from 25 to 35, and Participant 8's from 40 to 60. Although not as drastic as the changes that achieved the highest score, these enhancements nonetheless demonstrate significant progress in performance, suggesting that the intervention has a favorable impact across a range of baseline performance levels. A few students made no improvements or their scores remained the same, for example Participant 16's score was 15 in both tests, suggesting that the intervention had no noticeable impact on this individual. Participant 10 had a decline from 45 to 20. Nevertheless, the MR group overall demonstrated a notable and statistically significant improvement in test scores after the intervention, with a considerable number of individuals making meaningful progress.

To evaluate the impact of the intervention, the disparity between the pre-test and post-test scores were calculated for each group. Results are summarized in Table 1 and the outcomes of the paired difference t-test are presented in Table 2.

Table 1

Delta of the Non-MR Group and the MR Group

Non-MR Group				MR Group			
No.	Pre-Test	Post-test	Delta	No.	Pre-Test	Post-test	Delta
1	60	70	-10	1	50	100	-50
2	50	70	-20	2	80	100	-20
3	35	60	-25	3	50	100	-50
4	40	65	-25	4	50	100	-50
5	30	70	-40	5	45	90	-45
6	45	55	-10	6	20	55	-35
7	30	60	-30	7	25	35	-10
8	50	50	0	8	40	60	-20
9	95	30	65	9	15	40	-25
10	35	100	-65	10	45	20	25
11	30	20	10	11	40	65	-25
12	50	40	10	12	45	70	-25
13	55	20	35	13	50	75	-25
14	60	45	15	14	70	90	-20
15	65	75	-10	15	40	75	-35
16	45	20	25	16	15	15	0
17	40	60	-20	17	40	80	-40
18	55	70	-15	18	15	100	-85
19	55	55	0	19	15	100	-85
20	45	95	-50	20	15	85	-70
21	65	90	-25				
22	65	95	-30				

Table 2

Non-MR Group and MR Group Paired Difference t-test Result

Non-MR Group t-test Result			MR Group t-test Result		
Null Hypothesis	p-value	$\alpha = 1\%$	Null Hypothesis	p-value	$\alpha = 1\%$
$H_0: m_1 - m_2 = 0$	0.1295527	Accept	$H_0: m_1 - m_2 = 0$	0.0000144	Reject
$H_0: m_1 - m_2 \geq 0$	0.0647763	Accept	$H_0: m_1 - m_2 \geq 0$	0.0000072	Reject

$H_0: m_1 - m_2 \leq 0$	0	0.9352237	Accept	$H_0: m_1 - m_2 \leq 0$	0	0.9999928	
-------------------------	---	-----------	---------------	-------------------------	---	-----------	--

The mean discrepancy (Delta) between the pre-test and post-test scores for the non-MR group was -9.7727, suggesting a general enhancement in student performance. The standard deviation of the differences was 29.0516. Although there has been an improvement, the statistical analysis indicates that the results are not statistically significant at the 1% level of significance. The t-test statistic was calculated to be -1.5778 with 21 degrees of freedom, yielding a p-value of 0.1295527. The p-value above the threshold of 0.01 indicates that the null hypothesis ($H_0: m_1 - m_2 = 0$) can be accepted at a significance level of 1%. Additionally, when alternative assumptions are taken into account, a further analysis of the null hypothesis also confirms this finding. The p-value for the one-tailed test with the null hypothesis ($H_0: m_1 - m_2 \geq 0$) was 0.0647763, while for the opposite one-tailed test ($H_0: m_1 - m_2 \leq 0$), it was 0.9352237. Both p-values surpass the 1% significance threshold, implying that both null hypotheses are accepted. To summarize, although there is some indication of improved performance among students in the non-MR group, the evidence is not sufficiently robust.

The findings of the paired t-test for the MR group present convincing evidence on the efficacy of the MR educational intervention. The mean discrepancy (Delta) between the pre-test and post-test scores for this group was -34.5, suggesting a significant enhancement in student performance. The standard deviation of the differences was 26.7001, indicating a certain degree of variation, suggesting a significant general trend of improvement. The t-test statistic was calculated to be -5.7786 with 19 degrees of freedom, leading to a very small p-value of 0.0000144. The p-value is significantly lower than the 1% significance threshold, indicating that the null hypothesis ($H_0: m_1 - m_2 = 0$) can be rejected at the 1% significance level. This suggests compelling evidence that the MR use had a substantial and beneficial effect on the students' academic achievements. An additional examination of the one-tailed hypotheses provides further evidence for this result. The p-value for the null hypothesis ($H_0: m_1 - m_2 \geq 0$) was 0.0000072, while for the alternative one-tailed hypothesis ($H_0: m_1 - m_2 \leq 0$), it was 0.9999928. The test's exceptionally low p-value, which rejects the null hypothesis $H_0: m_1 - m_2 \geq 0$, confirms that the intervention resulted in a considerable rise in scores, as anticipated. To summarize, the use of MR during instruction had a considerable positive impact on student performance, as indicated by the strong statistical significance of the t-test results.

The findings of the paired t-tests for the non-MR and MR groups show a clear difference in the effectiveness of the two educational programs. The group without MR, which had an average improvement of -9.7727 and a standard deviation of 29.0516, did not provide statistically significant findings ($p = 0.1295527$). The existence of substantial outliers and the heterogeneity in individual results indicate that the non-MR approach had inconsistent effects on the students. On the other hand, the MR group showed a significant and consistent improvement in performance, with an average difference of -34.5 and a standard deviation of 26.7001. The t-test conducted on the MR group produced a very significant outcome ($p = 0.0000144$), indicating strong evidence that the MR use successfully improved student learning results. The one-tailed tests show substantial p-values, which strongly support this finding. These p-values indicate that the MR strategy not only increased scores but did so with a high level of confidence. The findings emphasize the greater effectiveness of MR technology in educational environments

when compared to traditional approaches, indicating that MR could be a significant tool for enhancing student engagement and boosting learning outcomes.

Following this, a statistical test was applied to determine whether there was a significant distinction between the means of the two groups. This method is often used when comparing the averages of two groups to determine if they demonstrate statistically significant differences. Table 3 below presents a summary of the score differences between the two groups. A chart is used to visually compare the pre-test and post-test scores of the two groups. Additionally, the results of the t-test for the difference in means are provided.

Table 3

Summary of Delta from Each Group

No.	Non-MR Group Delta	MR Group Delta
1	10	50
2	20	20
3	25	50
4	25	50
5	40	45
6	10	35
7	30	10
8	0	20
9	-65	25
10	65	-25
11	-10	25
12	-10	25
13	-35	25
14	-15	20
15	10	35
16	-25	0
17	20	40
18	15	85
19	0	85
20	50	70
21	25	
22	30	

Table 4*t-Test for Differences in the Population Means*

Non-MR Group t-test Result			
Null Hypothesis		p-value	$\alpha = 1\%$
$H_0: m_1 - m_2 =$	0	0.0067	Reject
$H_0: m_1 - m_2 \geq$	0	0.0033	Reject
$H_0: m_1 - m_2 \leq$	0	0.9967	Accept

Before the t-test was performed, the differences between pre-test and post-test scores (called *delta*) were calculated for both the non-MR and MR groups (see Table 3). The *delta* represents how much each student's score changed after the learning session. In the non-MR group, the changes varied widely—from a large drop of -65 points to an increase of 65 points. Some students showed improvement, others had no change, and a few even performed worse after the session. In contrast, the MR group had mostly positive deltas, with several students improving by 20 points or more, and some reaching up to 85 points of improvement. This suggests that, overall, students in the MR group gained more from the learning experience compared to the non-MR group.

To better understand if these changes were statistically meaningful for the non-MR group, a paired t-test was used (see Table 4). This test compared the average scores before and after the learning. The first hypothesis ($H_0: m_1 - m_2 = 0$) assumed no difference between the pre-test and post-test averages. Since the p-value (0.0067) was less than 0.01, we rejected this hypothesis. This means there was some difference in scores, though not necessarily a strong one.

The second hypothesis ($H_0: m_1 - m_2 \geq 0$) assumed that students either did worse or stayed the same after learning. The p-value here was 0.0033, again below 0.01, so this hypothesis was also rejected. This indicates that the post-test scores were generally a bit higher. The third hypothesis ($H_0: m_1 - m_2 \leq 0$) proposed that the students' performance either stayed the same or improved. The p-value was 0.9967, much higher than the 0.01 threshold, so we accepted this one. This means it's likely that students improved slightly, but the improvement was not strong or consistent across the group.

Overall, while some individuals in the non-MR group did improve, the group as a whole did not show significant learning progress. The t-test results support this, suggesting only a minor change that cannot be confidently considered a meaningful learning gain.

SPRADO Assessment Findings

The evaluation of teaching and learning in the MR group, as assessed by both the students and teachers using the SPRADO assessment tool, is presented below.

The findings from the teacher evaluations suggest that the MR environment was well-received and perceived as a valuable instructional enhancement. Teachers consistently rated the environment positively across a wide range of dimensions (see Table 5), particularly in terms of improving the effectiveness of content delivery, providing better visualization, and enabling safe engagement with complex tasks—each receiving the highest mean scores (3.56). These results suggest that the MR environment is especially effective in supporting practical, hands-on learning that may be difficult to replicate through traditional instruction. Teachers also reported that the MR environment contributed to a sense of special presence and offered new perspectives in the learning process. While several aspects such as increased student engagement, confidence, and communication showed solid support, the lowest-rated item (“making classroom management easier”) suggests that logistical or classroom control elements may be an area where MR integration presents challenges.

The SPRADO assessment tool also offered valuable insights into students’ perceptions and experiences with this educational technology. Students consistently reported high levels of pleasure and engagement with learning across multiple dimensions (see Table 6). The consistently high ratings for elements such as enhanced engagement with learning topics, heightened learning motivation, and improved efficacy of the learning process suggest that MR contributed positively to the students’ educational experience. Overall, the data indicate that students found MR to be an engaging, flexible, and supportive tool that enhanced both cognitive and affective aspects of their learning.

Teachers’ and students’ evaluations corroborate prior research showing that MR can improve student motivation, interaction with materials, and focus during lessons (Pellas et al., 2020; Tang et al., 2020; Tenberg, 2015). Teacher feedback highlighted MR’s ability to support the development of both physical (psychomotor) and thinking (cognitive) skills. These benefits have been found in other studies as well (Dascalu et al., 2014; Suryodiningrat et al., 2021; Touel et al., 2020). Additionally, students liked that MR allowed flexible and mobile learning, which shows that MR can meet different student needs. These findings echo the idea that MR can expand access to learning and support personal growth (Birt et al., 2018; John & Kurian, 2019; Vasilevski & Birt, 2020).

Table 5

Teachers’ Evaluation Results with SPRADO

No.	Statements	Sum	Mean	V
1	It increases the learning involvement or learning engagement.	31	3.44	0.247
2	It gives me more interactions with the learning topics.	29	3.22	0.173
3	It increases the learning outcomes.	28	3.11	0.099
4	It increases the effectiveness in transferring the learning materials.	32	3.56	0.247
5	The learning process is fun.	32	3.56	0.247
6	It provides better visualization.	31	3.44	0.469
7	It is more possible to collaborate with students at the same or different schools.	30	3.33	0.444

8	It provides more informative learning material.	31	3.44	0.247
9	It provides a safe atmosphere in carrying out learning that has the potential to be dangerous if done directly.	32	3.56	0.247
10	It supports complex scenarios. i.e., disassembling or assembling a car engine.	31	3.44	0.247
11	It increases the confidence level of students.	31	3.44	0.247
12	It can facilitate a systematic learning system.	31	3.44	0.247
13	It makes classroom management easier.	30	3.33	0.222
14	It makes communication between students and teachers better, easier, and more effective.	31	3.44	0.247
15	It provides a better flow in teaching.	32	3.56	0.247
16	It provides a spatial presence or is generally defined as a sense of “being there”.	32	3.56	0.247
17	It improves communication between students and teachers in the teaching and learning context.	31	3.44	0.247
18	It provides some new perspectives in the learning process.	32	3.56	0.247
19	I can do learning anywhere and I don't have to be at school if I have the appropriate tools.	31	3.44	0.247

Table 6*Students' Evaluation Results with SPRADO*

No.	Statements	Sum	Mean	V
1	It gives me more interactions with the learning topics.	68	3.4	0.340
2	It increases my learning motivation.	68	3.4	0.340
3	It makes my learning process more effective.	64	3.2	0.360
4	It gives me more experience in the learning process.	70	3.5	0.250
5	It improves my learning performance to be better.	64	3.2	0.460
6	The learning process becomes more immersive.	69	3.5	0.448
7	It improves my skills in learning.	71	3.6	0.248
8	It improves my creativity in learning.	74	3.7	0.210
9	It makes me more active in participating.	68	3.4	0.340
10	It improves my expertise or skills in the learning process.	71	3.6	0.248
11	I think the learning process is fun.	72	3.6	0.240
12	It provides better visualization.	67	3.4	0.328
13	It is more possible to collaborate with other students.	67	3.4	0.428
14	It can provide learning tailored to my preferences or personalized learning.	65	3.3	0.288
15	It can improve my cognitive skills.	67	3.4	0.228
16	It can provide more informative learning materials.	65	3.3	0.288
17	It makes me have a positive attitude.	65	3.3	0.488
18	It makes me have a positive impression.	70	3.5	0.250
19	It provides a safe atmosphere in carrying out learning that has the potential to be dangerous if done directly.	67	3.4	0.328
20	It supports complex scenarios, i.e., disassembling or assembling a car engine.	60	3.0	0.700
21	It provides a positive impact on psychomotor development.	64	3.2	0.460
22	It provides a spatial presence or is generally defined as a sense of "being there".	65	3.3	0.688
23	It improves communication between students and teachers in the teaching and learning context.	68	3.4	0.240
24	It improves my judgment ability.	66	3.3	0.310
25	It improves my logic skills.	70	3.5	0.250
26	It increases my level of independence in learning.	69	3.5	0.348
27	It provides better learning satisfaction.	66	3.3	0.310
28	It provides some new perspectives in the learning process.	67	3.4	0.228
29	It stimulates my creativity.	71	3.6	0.348
30	I can do learning anywhere and I don't have to be at school as long as I have the appropriate tools.	69	3.5	0.248

To ensure the reliability of teachers' and students' evaluations, internal consistency was assessed using Cronbach's alpha. Tables 7 and 8 present the reliability coefficients for the teacher and student responses to the SPRADO assessment tool.

Table 7

Cronbach's α Result from Teachers

No. of Questions	19
No. of Item Variance	4.864
Total Score of Variance	62
Cronbach α	0.973

Table 8

Cronbach's α Result from Students

No. of Questions	30
No. of Item Variance	10.233
Total Score of Variance	123.63
Cronbach α	0.949

The Cronbach α reliability statistics indicate that the teacher assessments (Table 5) yielded a coefficient of 0.973, and the student assessments (Table 6) yielded a coefficient of 0.949. Both values reflect a very high level of internal consistency. Cronbach's α values approaching 1 indicate a stronger reliability, suggesting that the items in the SPRADO assessment were consistently interpreted and rated by respondents. In this case, the high coefficients demonstrate a strong degree of agreement among the items in each form, indicating that the instrument reliably measured a unified set of constructs. Put simply, the respondents rated items in a consistent manner, suggesting that they were accurately assessing the same fundamental concepts. When employing a 4-point Likert scale in an assessment form, this high level of consistency supports the validity of the obtained data.

Conclusion

In this quasi-experiment with a pre-test/post-test design, the results revealed notable findings that highlight the effectiveness of MR use in vocational education. The MR group demonstrated greater improvement between pre and post test scores compared to the non-MR group, indicating that MR technology can enhance learning outcomes, particularly in machinery-focused vocational programs. A paired difference t-test confirmed this effect, showing a

statistically significant difference between the scores obtained in the pre-test and post-test, highlighting the effectiveness of the MR intervention. Furthermore, the t-test for the differences in population means resulted in the rejection of the null hypothesis, confirming a significant improvement for the MR group. Together, these findings further validate the efficacy of the MR-based training.

Teachers' and students' evaluations of the teaching and learning environment in the MR-group indicated that the MR-supported instruction was well-received as an engaging, effective, and supportive instructional approach, enhancing both cognitive and practical aspects of learning. The feedback emphasized MR's potential to increase student motivation and engagement, facilitate hands-on learning, create a flexible learning experience, and improve communication between students and teachers. The reliability of the SPRADO assessment tool used by teachers and students in this evaluation was supported by high Cronbach's alpha coefficients, which yielded findings of 0.973 for teachers and 0.949 for students. These values indicate strong internal consistency across the items in the evaluation form, suggesting that SPRADO is a dependable instrument for evaluating MR systems in educational settings.

It is important to acknowledge the study's limitations. The research involved a small and specific sample of 42 students and 9 teachers. Furthermore, the intervention was carried out over a single session. These limitations may impact the generalizability of the results and highlight the need for further studies involving larger and more diverse populations. This study also focused specifically on students in automotive technology programs.

Despite these limitations, the findings have important implications for the design and delivery of technical education. MR provides an engaging learning environment that connects academic knowledge with practical applications. By simulating practical setting for skill development, MR aligns well with modern educational priorities, which emphasize experiential and student-centered learning. It serves not only as a technological enhancement but also as a bridge between theory and practice in vocational education.

In the context of Indonesian machinery vocational schools, particularly in rural areas, the integration of MR technology offers notable advantages. Firstly, it promotes the standardization of learning materials and instructional methods, helping to ensure consistent quality in educational delivery, in alignment with the rules set by the Ministry of Education, Culture, Research, and Technology. Additionally, MR allows students to virtually engage with cutting-edge equipment, offering exposure to the tools and processes that may not be accessible in traditional classroom environments. Furthermore, the standardization of MR content can guarantee that students in both rural and urban locations have equal access to high-quality education.

Future research should explore the integration of artificial intelligence (AI) and machine learning (ML) to augment the functionalities of MR systems. Investigations should prioritize collaborative learning, training, and assessments utilizing MR technology in machinery vocational schools. To accurately measure educational results, it is necessary to conduct specialized research that involves collecting data at regular intervals over one semester or a complete academic year.

This approach would provide a more comprehensive understanding of the long-term effects of MR interventions.

Declarations

Availability of data and materials: Not applicable.

Competing interests: The authors declare that they have no conflicts of interest.

Funding: Not applicable.

Author contribution section: The authors declare that they have co-written the article and share authorship among them.

Acknowledgments: Not applicable.

References

- Adams, J., Flavell, F., & Raureti, R. (2022). Mixed reality results in vocational education: A case study with HoloLens 2. *Research in Learning Technology*, 30. <https://doi.org/10.25304/rlt.v30.2803>
- Béduwé, C., & Giret, J. F. (2011). Mismatch of vocational graduates: What penalty on French labour market? *Journal of Vocational Behavior*, 78(1), 68–79. <https://doi.org/10.1016/j.jvb.2010.09.003>
- Birt, J., Stromberga, Z., Cowling, M., & Moro, C. (2018). Mobile mixed reality for experiential learning and simulation in medical and health sciences education. *Information (Switzerland)*, 9(2), 1–14. <https://doi.org/10.3390/info9020031>
- Boel, C., Dekeyser, K., Lemal, M., Rotsaert, T., Valcke, M., Schellens, T., & Struyf, D. (2023). Towards a framework for a nation-wide implementation of augmented, virtual and mixed reality in K-12 technical and vocational education. *TechTrends*. <https://doi.org/10.1007/s11528-023-00925-y>
- Dascalu, M. I., Moldoveanu, A., & Shudayfat, E. A. (2014). Mixed reality to support new learning paradigms. *2014 18th International Conference on System Theory, Control and Computing, ICSTCC 2014*, 692–697. <https://doi.org/10.1109/ICSTCC.2014.6982498>
- Durmus, A., & Dağlı, A. (2017). Integration of vocational schools to Industry 4.0 by updating curriculum and programs. *International Journal of Multidisciplinary Studies and Innovative Technologies*, 1(1), 1–3.
- Heaviside, H. J., Manley, A. J., & Hudson, J. (2018). Bridging the gap between education and employment: A case study of problem-based learning implementation in postgraduate sport and exercise psychology. *Higher Education Pedagogies*, 3(1), 463–477. <https://doi.org/10.1080/23752696.2018.1462095>
- HoloLens 2—Overview, Features, and Specs | Microsoft HoloLens*. (n.d.). <https://www.microsoft.com/en-us/hololens/hardware>
- Holstein, K., McLaren, B. M., & Alevén, V. (2018). Student learning benefits of a mixed-reality teacher awareness tool in AI-enhanced classrooms. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 10947 LNAI*. Springer International Publishing. https://doi.org/10.1007/978-3-319-93843-1_12
- Imam Agung, A., Mukhadis, A., Sutadji, E., & Purnomo. (2018). Embedding entrepreneurs in improving the skills of entrepreneurs of technology based vocational school in Indonesia. *IOP Conference Series: Materials Science and Engineering*, 336(1). <https://doi.org/10.1088/1757-899X/336/1/012043>

- Jaya, H., Haryoko, S., Lu'mu, & Ida, P. (2020). Use of remote lab for online and real time practicum at vocational school in Indonesia. *International Journal of Online and Biomedical Engineering*, 16(5), 4–14. <https://doi.org/10.3991/IJOE.V16I05.13201>
- John, B., & Kurian, J. (2019). Making the world a better place with mixed reality in education. *Australasian Conference on Information Systems*, 344–354.
- Maas, M. J., & Hughes, J. M. (2020). Virtual, augmented and mixed reality in K–12 education: A review of the literature. *Technology, Pedagogy and Education*, 29(2), 231–249. <https://doi.org/10.1080/1475939X.2020.1737210>
- Moon, S. H., Jeong, H., & Choi, M. J. (2024). Integrating mixed reality preparation into acute coronary syndrome simulation for nursing students: A single-group pretest-posttest study. *BMC Nursing*, 23(1). <https://doi.org/10.1186/s12912-024-02110-9>
- Morimoto, T., Kobayashi, T., Hirata, H., Otani, K., Sugimoto, M., Tsukamoto, M., Yoshihara, T., Ueno, M., & Mawatari, M. (2022). XR (extended reality: Virtual reality, augmented reality, mixed reality) technology in spine medicine: Status quo and quo vadis. *Journal of Clinical Medicine*, 11(2). <https://doi.org/10.3390/jcm11020470>
- Ogunseiju, O. R., Gonsalves, N., Akanmu, A. A., Bairaktarova, D., Bowman, D. A., & Jazizadeh, F. (2022). Mixed reality environment for learning sensing technology applications in Construction: A usability study. *Advanced Engineering Informatics*, 53, 101637. <https://doi.org/10.1016/j.aei.2022.101637>
- Pellas, N., Kazanidis, I., & Palaigeorgiou, G. (2020). A systematic literature review of mixed reality environments in K-12 education. *Education and Information Technologies*, 25(4), 2481–2520. <https://doi.org/10.1007/s10639-019-10076-4>
- Rokhsaritalemi, S., Sadeghi Niaraki, A., & Choi, S. M. (2020). A review on mixed reality: Current trends, challenges and prospects. *Applied Sciences*, 10(2), 636. <https://doi.org/10.3390/app10020636>
- Sievers, T. S., Schmitt, B., Rückert, P., Petersen, M., & Tracht, K. (2020). Concept of a mixed reality learning environment for collaborative robotics. *Procedia Manufacturing*, 45, 19 to 24. <https://doi.org/10.1016/j.promfg.2020.04.034>
- Smith, E., McRae, K., Semple, G., Welsh, H., Evans, D., & Blackwell, P. (2021). Enhancing vocational training in the post-COVID era through mobile mixed reality. *Sustainability*, 13(11), 6144. <https://doi.org/10.3390/su13116144>
- Suharno, Pambudi, N. A., & Harjanto, B. (2020). Vocational education in Indonesia: History, development, opportunities, and challenges. *Children and Youth Services Review*, 115(May), 105092. <https://doi.org/10.1016/j.childyouth.2020.105092>

- Suryodiningrat, S. P., Prabowo, H., Meyliana, & Hidayanto, A. N. (2021). Mixed reality system for teaching and learning: A systematic literature review. *2021 IEEE 5th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE)*, 387–392. <https://doi.org/10.1109/icitisee53823.2021.9655922>
- Suryodiningrat, S. P., Prabowo, H., Ramadhan, A., & Santoso, H. B. (2024). *SPRADO: The Assessment Tool for Mixed Reality Systems in Machinery Vocational Schools*. Any more publishing information?
- Suryodiningrat, S. P., Ramadhan, A., Prabowo, H., Santoso, H. B., & Hirashima, T. (2023). Mixed reality systems in education: A systematic literature review. *Journal of Computers in Education*. <https://doi.org/10.1007/s40692-023-00281-z>
- Tang, Y. M., Au, K. M., Lau, H. C. W., Ho, G. T. S., & Wu, C. H. (2020). Evaluating the effectiveness of learning design with mixed reality (MR) in higher education. *Virtual Reality*, 24(4), 797–807. <https://doi.org/10.1007/s10055-020-00427-9>
- Tenberg, R. (2015). Learning in a mixed reality system in the context of “Industrie 4.0.” *Journal of Technical Education (JOTED)*, 3(2).
- Touel, S., Marfisi Schottman, I., & George, S. (2020). Analysis of mixed reality tools for learning math in primary and secondary school. *Lecture Notes in Computer Science*, 12517, 112 to 121. https://doi.org/10.1007/978-3-030-63464-3_11
- Vasilevski, N., & Birt, J. (2020). Analysing construction student experiences of mobile mixed reality enhanced learning in virtual and augmented reality environments. *Research in Learning Technology*, 28(1063519), 1–23. <https://doi.org/10.25304/rlt.v28.2329>
- Wang, Q., & Li, Y. (2024). How virtual reality, augmented reality and mixed reality facilitate teacher education: A systematic review. *Journal of Computer Assisted Learning*, 40(3), 1276–1294. <https://doi.org/10.1111/jcal.12949>
- Yannier, N., Hudson, S. E., & Koedinger, K. R. (2020). Active learning is about more than hands on: A mixed reality AI system to support STEM education. *International Journal of Artificial Intelligence in Education*, 30(1), 74 to 96. <https://doi.org/10.1007/s40593-020-00194-3>