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Enhancing Vocational Student Achievement through a QR Code–Integrated Smart Trainer in Automotive Education

Wawan Purwanto[1]*, Hendra dani Saputra[1], Dwi sudarno Putra[1], Zaenal Abadi[1], Ahmad Arif[1], Irma Wirantina Kustanrika[2]

Abstract

This study investigates the effectiveness of a smart trainer integrated with QR code technology in improving student learning outcomes in vocational education. The trainer enables students to observe sensor voltage outputs and access corresponding theoretical explanations via QR codes linked to instructional videos. The research was conducted offline with 15 students and 5 teachers over four sessions, aligned with Phase F of the Merdeka Belajar curriculum. A pre-test and post-test design was applied to assess learning improvements. Results showed an average score increase of 12.5%, indicating enhanced cognitive understanding of motorcycle electronic systems. These findings demonstrate the potential of IoT-based learning tools to support self-directed learning and bridge theoretical and practical competencies. The approach also reflects the growing relevance of digital integration in technical education aligned with Industry 4.0 demands.

Keywords
Vocational education, smart trainer, QR code learning, student achievement, Internet of Things

[1]Department Teknik Otomotif Universitas Negeri Padang
Prof. Dr. Hamka Street, Air Tawar, Padang, Sumatera Barat, Indonesia
[2]Department of Civil Engineering, Technology Institute of PLN, Jakarta, Indonesia
Lingkar Luar Barat Duri Kosambi Street, Cengkareng, West Jakarta, Indonesia
** wawan5527@ft.unp.ac.id*

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INTRODUCTION

The goal of every educational process is to equip students with relevant competencies and high-level skills required in the professional world [1]. Fundamentally, all educational programs aim to improve student learning achievement, which refers to the extent to which learners acquire knowledge and skills. This achievement is commonly measured through course grades, standardized tests, and classroom assessments [2]. In vocational education, success is determined by the student's mastery of both theoretical concepts and practical skills [3][4][5][6].

Educators are essential in influencing students' learning outcomes, functioning both as facilitators and motivators in the classroom [7]. Disparities in student performance have been extensively ascribed to numerous teacher-related criteria, including cognitive capacity, self-assurance, pedagogical approach, engagement, and interpersonal communication [8]. Consequently, a teacher's capacity to adapt and innovate in pedagogical approaches significantly impacts student accomplishment. A significant instructional innovation is the use of interactive and engaging learning media, which can enhance students' attention and active involvement [9][10]. Within the framework of the Merdeka curriculum, which promotes student autonomy and self-directed learning, traditional media frequently proves inadequate. This is especially apparent in technical domains such as car electrical systems, where abstract concepts are challenging to comprehend without visual and tactile assistance.

The current era of the Fourth Industrial Revolution necessitates educational methodologies that are both competency-focused and outcome-driven. Creativity, along with the capacity to implement information in practical situations, has emerged as an essential asset [11]. Consequently, educators must possess suitable teaching resources, particularly project-based and case-based learning materials that foster creativity and innovation in the educational process. In automotive engineering, educators have created diverse simulation tools and trainers to enhance instructional efficacy. These trainers simulate actual industrial components and systems, offering students practical experiences that combine academic knowledge with technical skills. Notwithstanding continuous research and development in this domain, the implementation of such trainers in vocational schools is constrained by obstacles in financing, manufacturing scalability, and product distribution.

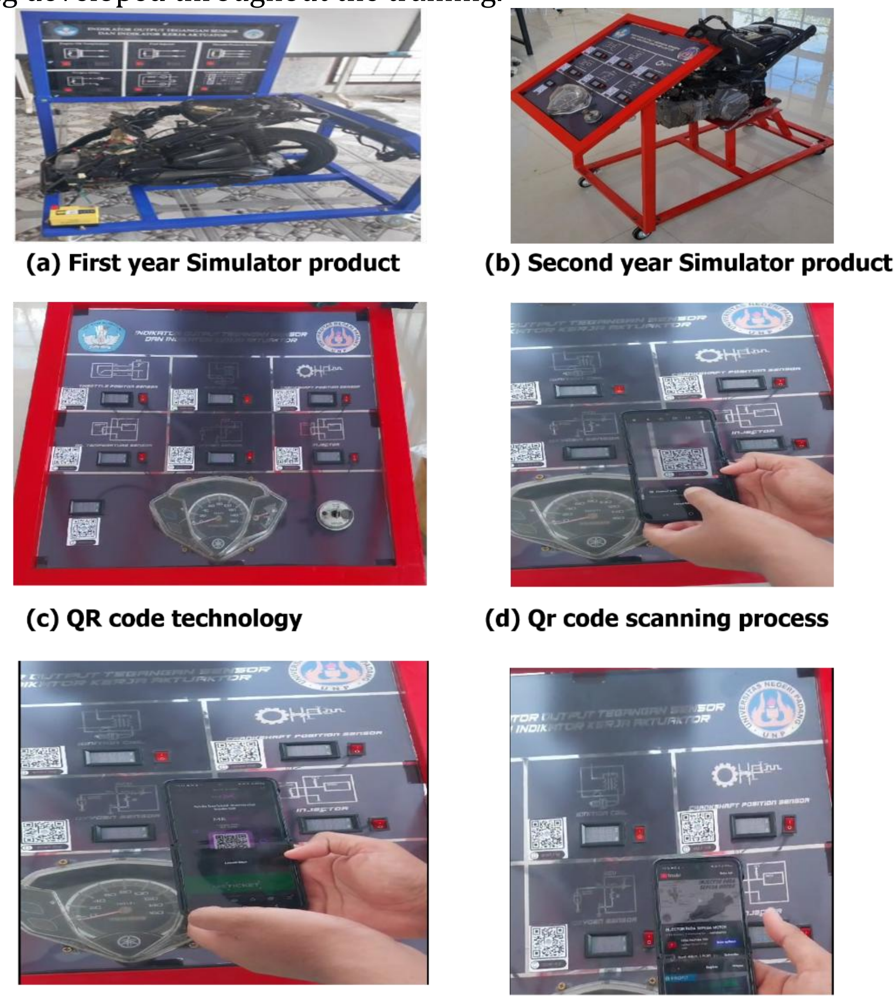
Research has developed various training simulators for automotive and motorcycle electronics, including models tailored for secondary and tertiary technical education programs [12]. These instruments allow students to investigate systems including sensors, electronic control units (ECUs), and ignition systems utilized in contemporary vehicles. The deployment of such devices enables educators to illustrate diagnostic operations, such as testing fuel pumps and injection systems, with greater efficacy. Moreover, the utilization of simulators can enhance the capability of practice groups, promoting more collaborative and efficient learning settings [13]. To properly utilize these breakthroughs, institutions must implement a holistic approach that includes product development, packaging, marketing, and commercialization. Every professor should actively participate in transforming research results into revenue-generating products. A committed marketing team should be formed to promote research goods and guarantee they fulfill the requirements of vocational institutions. However, the commercialization process must not encumber lecturers, whose principal duties are teaching, research, and community service.

Therefore, a promising solution is the integration of research-based products into a teaching factory model. Under this model, students participate in developing simulator products under the guidance of faculty researchers. This initiative not only supports vocational skills development but also contributes to the *Merdeka Belajar Kampus Merdeka* (MBKM) program, allowing students to earn academic credits while gaining real-world experience and completing their studies on time. This study presents a novel implementation of a smart automotive trainer integrated with QR code technology, contributing to the advancement of independent learning practices in vocational education and aligning with the competencies required in the context of Industry 4.0.

METHOD

This research was performed at SMK N 1 Lembah Melintang, where the final iteration of the smart trainer product was evaluated directly with a cohort of 15 students and 5 teachers from the automotive engineering program. The learning process lasted a total of 32 hours, split into two periods. The initial 16 hours were conducted by the core team of automotive engineering instructors, whilst the subsequent 16 hours were led by subject teachers who had previously undergone training on the trainer's utilization. The educational instrument utilized in this research is a trainer created by university faculty, with its iterations depicted in Figure 1. The initial version (Figure 1a) exhibited solely the output voltage of each sensor, necessitating students to consult supplementary materials to comprehend the sensor's operation. This method required much student effort and self-motivation. In the second-year iteration (Figure 1b), the trainer was augmented with QR code technology (Figure 1c), allowing students to scan the code and receive video-based theoretical explanations on YouTube. This integration facilitated more efficient autonomous learning, particularly in comprehending the concepts of vehicle sensing systems. The implementation occurred during August and September 2024. To assess the trainer's efficacy, students underwent a pre-test prior to the intervention and a post-test following the completion of the instructional sessions. The disparity in scores was subsequently examined to evaluate enhancements in student learning outcomes.

Despite providing valuable insights, this study acknowledges several limitations. The relatively small sample size (n = 20) restricts the generalizability of the findings to broader student populations. Moreover, the short duration of implementation may limit the observation of long-term impacts on student comprehension and retention. The study also lacked controls for external variables such as students' prior knowledge, individual motivation, and the classroom learning environment, which could influence learning outcomes. Bias in data collection cannot be entirely ruled out. Respondents' enthusiasm toward new technology may have introduced the Hawthorne effect, while researchers' expectations may have led to confirmation bias in interpreting the results. Furthermore, the current version of the trainer focuses only on specific sensor components and may not capture the full complexity of modern vehicle systems. While pre-test and post-test comparisons provide useful indications of learning improvement, they may not fully reflect the depth of knowledge transfer or conceptual understanding developed throughout the training.



(a) First year Simulator product **(b) Second year Simulator product**

(c) QR code technology **(d) Qr code scanning process**

(e) Scan display process **(f) Direction to YouTube channel**

Figure 1. QR code technology in smart trainers

RESULT AND DISCUSSION

The implementation of the smart trainer integrated with QR code technology was conducted to validate its use as an alternative learning tool, particularly in Phase F of the Merdeka Belajar curriculum for motorcycle engineering and business program. The training activity involved 15 students and 5 teachers from SMK N 2 Lembah Melintang, and the learning process was documented in various stages, as illustrated in Figure 2. As shown in Figures 2a–2d, there was active interaction between students and teachers during the training. Students were also given the opportunity to independently use the trainer by scanning QR codes with their mobile phones (Figures 2e–2f), which allowed them to access instructional videos and deepen their understanding of vehicle sensor systems.

a. Preliminary material teaching session

b. Q&A session with student

c. Intensive discussion with students

d. Discussion session with students on the product

e. Students try to scan the QR code on the sensor they learnt about.

f. Students scan their mobile phones

Figure 2. Implementation of smart trainers in teaching processes

Furthermore, Figure 3 illustrates a comparison of students' achievement scores across three phases: before training, following the first-year implementation, and after the second-year implementation with the enhanced trainer. An evident rising tendency is noted, where the mean score prior to training was roughly 7, which elevated to 8 following the implementation of the first-year trainer. After the second-year upgrade incorporating QR code integration, the average score rose to 9. This progressive enhancement indicates a beneficial effect of the training on students' comprehension of motorbike electronic systems. The upward trend across these phases highlights the significant role that interactive, technology-enhanced media can play in supporting vocational learning. The second-year trainer provided not only sensor output data but also instant access to theoretical explanations through QR codes linked to YouTube videos. This multi-modal approach combining hands-on experience with accessible multimedia content appears to enhance knowledge retention and understanding. It aligns with findings that students benefit from blended learning environments, especially when abstract technical concepts, such as sensor functionality and ECU systems, are involved.

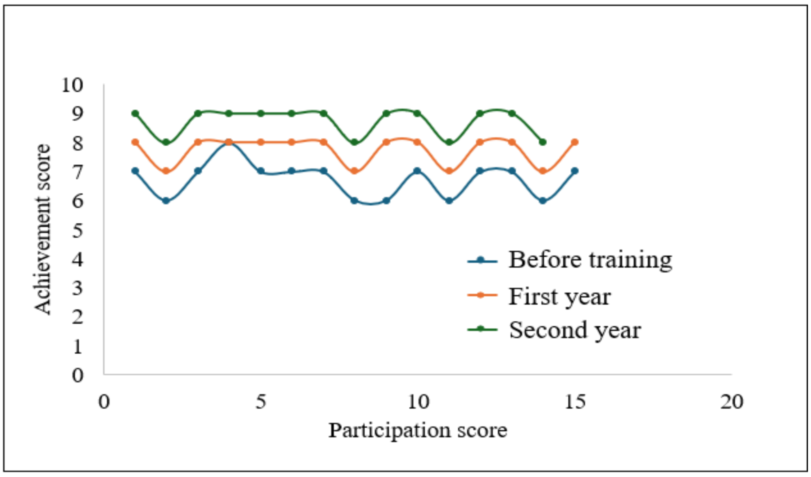


Figure 3. Achievement score of students

Based on pendagogical standpoint, this outcome illustrates that the smart trainer endorses the constructivist learning approach, wherein students acquire information via experience and exploration. Students actively engage with practical tools and contextual information instead of being passive recipients. The utilization of QR codes capitalizes on students' digital literacy and proficiency with mobile technologies, connecting formal education with casual learning practices. The incorporation of IoT-based technology in education, as demonstrated by this trainer, signifies the extensive change instigated by the Fourth Industrial Revolution. IoT technology enables continuous data connection between systems and users, and its implementation in education promotes more dynamic, personalized, and efficient learning processes. Prior research indicates that proficiency in programming and microcontroller technology is increasingly vital for vocational skills in Industry 4.0 [6][14]. The trainer in this study serves as a conduit for students to engage with these systems in a reduced, classroom-oriented fashion.

This study further confirms the perspective that IoT-driven educational tools are not simply a technological innovation, but a pragmatic solution to the changing requirements of contemporary learners. Students' capacity to access educational content at any location and time via QR codes reflects real-world industrial practices, where digital integration and remote diagnostics are commonplace. The favorable findings further corroborate other studies emphasizing the significance of IoT applications in enhancing student performance and engagement across diverse educational environments [15][16][17].

In summary, the findings of this research substantiate that the incorporation of QR code-based learning within vocational training significantly improves student performance, especially in technical fields necessitating both theoretical comprehension and practical competencies. This finding holds significant implications for vocational education providers seeking to enhance their instructional methodologies. The instructor not only focuses on the delivery of content but also fosters independent learning, critical thinking, and technological proficiency, each of which constitutes a vital competency for graduates within the framework of Industry 4.0.

CONCLUSION AND RECOMENDATION

Conclusion

This study illustrates the efficacy of a smart trainer including QR code technology in improving student performance in vocational education, specifically regarding motorcycle electronic systems. The instructor facilitated self-directed learning by allowing students to access theoretical content via mobile devices while participating in practical exercises. The implementation demonstrated a quantifiable enhancement in student outcomes, with an average rise of 12.5% in achievement scores, signifying a more robust intellectual and practical comprehension of the curriculum. The study demonstrates that incorporating IoT-based tools into vocational education helps reconcile theoretical knowledge with practical implementation. The integration of multimedia resources, interactivity, and real-time access to educational content mirrors contemporary industry standards and caters to the requirements of digital-native learners. This method may be applicable across other technological fields beyond automotive engineering. This study enhances the existing research on technology-enhanced learning in vocational education and indicates a viable direction for future innovation. The results emphasize the necessity of synchronizing educational resources with industrial requirements and contemporary teaching methodologies to adequately equip students for the challenges of industrial 4.0.

Recommendation

Future research should explore the scalability of this trainer by testing its implementation in different school environments, including urban and rural vocational institutions, and across various educational levels. Additionally, further development could focus on expanding the trainer's functionality to cover broader vehicle systems or integrate feedback mechanisms, adaptive content, or augmented reality components. These advancements could deepen student engagement and further personalize the learning experience.

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