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Empowering Remote Vocational Schools with VocaTeach to Bridge Skills Gaps in the Era of Industry 4.0 and Society 5.0

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Abstract: This study presents the development and implementation of VocaTeach, a web-based application designed to enhance project-based learning in the context of automotive vocational education. Motivated by the growing need to align vocational training with Industry 4.0 competencies, VocaTeach integrates digital project management, collaboration tools, and a comprehensive evaluation system to support both teachers and students in managing complex, real-world automotive tasks. The system was developed using an Agile methodology and deployed at SMK Swasta Pembda Nias, a vocational school in a geographically remote region. A mixed-method approach was employed, combining surveys, interviews, and usage analytics to assess the platform's effectiveness. Results showed a significant increase in student engagement (85%), peer collaboration (150% rise in interactions), and improved academic outcomes, including an 18% gain in theoretical test scores. Teacher workload decreased by up to 30%, reflecting improved efficiency in project supervision and assessment. Statistical analysis confirmed the significance of these improvements ($p < 0.05$) with a large effect size (Cohen's $d = 0.8$). Qualitative data reinforced these findings, with students reporting enhanced motivation and perceived relevance of learning tasks, while teachers highlighted improved structure and fairness in assessment. The study concludes that VocaTeach is a viable and scalable digital innovation for vocational education, especially in underserved regions. Future research is recommended to explore integration with Industry 5.0 technologies and to evaluate long-term impacts on career readiness and skill mastery.

Keywords: Project-Based Learning; Vocational Education; Automotive Training; Web Application; Digital Assessment; Industry 4.0; Society 5.0.

1. Introduction

Vocational education plays a pivotal role in preparing skilled labor forces to meet the dynamic demands of industrial sectors [1]–[3]. In the era of Industry 4.0, where automation, smart technologies, and data-driven decision-making dominate, the need for a workforce equipped with not only technical knowledge but also problem-solving, collaboration, and digital competencies is

more urgent than ever. Moreover, the global shift toward Society 5.0 emphasizes the integration of human-centered technology into all aspects of life, further challenging educational institutions to adapt their methodologies and learning tools [4]–[6].

Automotive vocational education is particularly affected by these transformations. Emerging trends such as electric vehicles, advanced driver assistance systems (ADAS), and digital diagnostics have redefined the skill requirements for automotive technicians [7]–[9]. Traditional teaching approaches often fall short in equipping students with the multifaceted competencies required by modern industry. There is thus a critical need for innovative learning models that not only deliver technical content but also simulate real-world working conditions, foster teamwork, and encourage independent learning.

Project-Based Learning (PBL) has been widely recognized as an effective pedagogical strategy in vocational contexts [10]–[12]. It enables students to engage in authentic, hands-on experiences that mirror workplace challenges, thus enhancing their readiness for professional environments. However, implementing PBL in under-resourced and remote areas poses several challenges, such as limited access to technological infrastructure, difficulty in monitoring project progress, and constrained teacher capacity [13], [14].

To address these gaps, this study presents the development of VocaTeach, a web-based application designed to support project-based learning in automotive vocational education, particularly in remote and underserved regions. Developed using an Agile methodology and built on PHP, MySQL, and Bootstrap technologies, VocaTeach enables instructors to create, manage, and assess student projects more effectively, while providing students with a collaborative platform to engage in structured and trackable learning tasks.

This study aims to explore the design, implementation, and evaluation of VocaTeach, and to analyze its impact on student engagement, problem-solving abilities, and collaboration skills. The research also investigates how such a digital tool can bridge the technological and pedagogical gap in vocational institutions situated in peripheral areas, contributing to the broader discourse on inclusive education in the digital age. Ultimately, VocaTeach offers a scalable model for integrating PBL and technology to prepare vocational students for active participation in Industry 4.0 and Society 5.0 ecosystems.

2. Material and methods

2.1 Research Design

This study employed a research and development (R&D) approach using the Agile development model to guide the creation of VocaTeach, a web-based

learning application. The Agile methodology was selected due to its iterative nature, which allows for continuous refinement based on user feedback [15]–[17]. This was particularly important given the dynamic and context-specific requirements of vocational education, especially in under-resourced environments. Through Agile's incremental cycles, the system was continuously evaluated and improved throughout the development process.

2.2 Research Site and Participants

The research was conducted in a private vocational high school specializing in automotive engineering, located in a remote area of Indonesia. The site was selected due to its challenges in delivering technology-integrated learning and its commitment to adopting innovation in vocational education. The participants included ten automotive subject teachers and thirty students, all of whom were involved in either the needs assessment, development feedback, or system testing stages.

2.3 Technology Stack

The VocaTeach application was developed using PHP 7.4 for backend development, applying a custom Model-View-Controller (MVC) structure to ensure modularity and maintainability. MySQL 8.0 was used as the database management system due to its scalability and compatibility with PHP. For the user interface, Bootstrap 5 was implemented to support responsive design across different devices, while vanilla JavaScript enabled client-side interactions. Git version control was used throughout the project to manage code revisions and ensure development integrity.

2.4 Development Process

The development process began with a comprehensive needs analysis. This included interviews with teachers and students, classroom observations, and curriculum document analysis to determine the instructional gaps and user expectations. The system design phase involved creating flowcharts and entity relationship diagrams (ERDs) to plan out the structure of the database and user interface. Implementation followed with the development of backend modules using PHP and frontend components with HTML, CSS, and JavaScript. Testing was conducted using both black-box (functional) and white-box (code logic) techniques to verify reliability and accuracy. Finally, the application was deployed on the school's local server using Apache and MySQL, ensuring accessibility within the school network.

2.5 System Workflow

To demonstrate the internal structure of the application and user interaction flow, a system flowchart was developed. This flowchart illustrates the complete

sequence from user login to final project evaluation and report generation. The workflow begins when users log in and are directed to role-specific dashboards. Teachers can create new projects, define task steps, assign students into teams, and monitor project completion. Students can view their team projects, complete step-by-step tasks, upload deliverables, and track their progress. Once a project is completed, the teacher performs an evaluation—both individual and group-based—and the system generates a comprehensive learning report. This structured workflow supports the principles of project-based learning by enabling collaborative task management and systematic performance tracking.

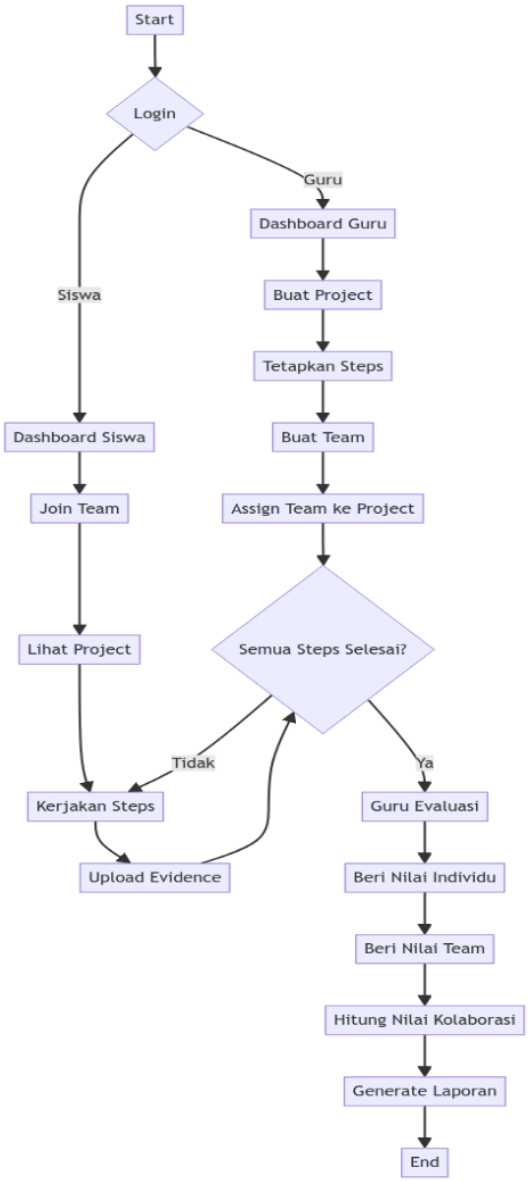

Figure 1. System Flow of the VocaTeach Application

The flowchart below outlines the operational logic of the VocaTeach application.

Upon logging in, users are directed to their designated dashboard based on their role—either teacher or student. Teachers can initiate new projects, divide tasks into steps, assign student teams, and later evaluate the results. Students, on the other hand, can join project teams, access project details, execute assigned steps, and upload their deliverables as evidence. The system continuously checks for project progress. Once all steps are completed, it allows teachers to assign final grades, both individually and collectively. The process concludes with the generation of a project completion report. This flow ensures that project-based learning is implemented in a structured and traceable manner, enhancing both instructional delivery and student engagement.

2.6 Data Collection

Data collection was conducted through a multi-method approach. Observational data were gathered during classroom implementation sessions where VocaTeach was used. Interviews with teachers and students provided qualitative insights into the system's usability and impact on learning behavior. Additionally, user satisfaction was assessed using structured questionnaires employing Likert scales. System usage logs were also collected to analyze patterns such as frequency of logins, number of tasks completed, and time spent per project phase.

2.7 Data Analysis

The collected data were analyzed using both qualitative and quantitative methods. Quantitative survey data were statistically processed to determine levels of user satisfaction and system effectiveness. Log data were analyzed descriptively to track engagement and feature utilization. Qualitative data from interviews and observations were thematically coded to identify user experiences, challenges, and perceived benefits of the system. Furthermore, technical performance was assessed based on application response time, task completion success rate, and error occurrence during usage.

3. Results and discussion

The development of VocaTeach resulted in a functional web-based application specifically designed to enhance project-based learning in the automotive vocational education domain. The application includes several key features that align with curricular goals and digital learning strategies.

3.1 Project Management System

The project management feature in VocaTeach enables teachers to create structured learning experiences that align with the automotive curriculum. This module is central to orchestrating project-based learning cycles, from defining

project objectives to assigning tasks and monitoring student progress in real time.

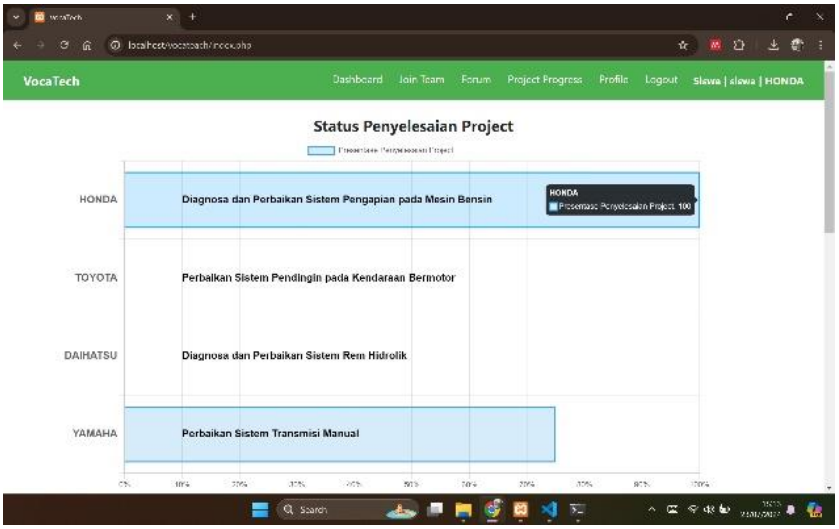

Figure 2. Teacher Dashboard – Project Status Overview

This figure displays the teacher's main dashboard interface. Each project created is listed along with its progress indicator, allowing the teacher to observe the status of multiple ongoing projects at a glance. Visual indicators provide insights into whether a project is on schedule, pending, or completed, enabling timely interventions.

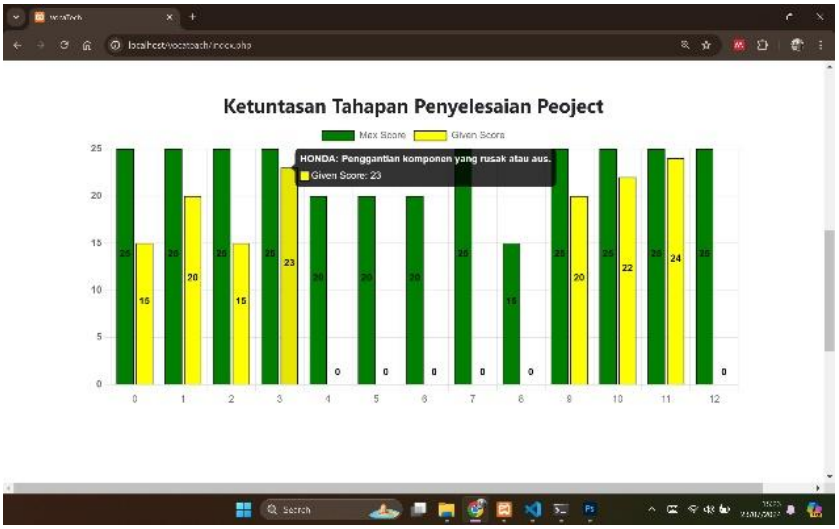

Figure 3. Teacher Dashboard – Task Step Completion

This screen allows teachers to delve deeper into project execution. It presents a breakdown of each project's task components and indicates which student groups have completed specific steps. This feature supports formative monitoring, allowing teachers to address learning delays at the task level.

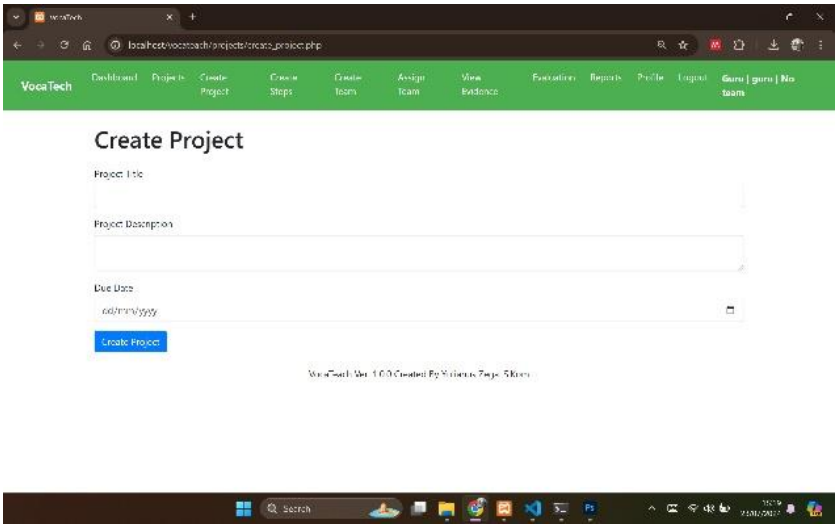

Figure 4. Project Creation Interface

The project creation interface is a form-based screen that teachers use to design new learning projects. It includes fields to input the project title, objectives, step-by-step instructions, and required outputs. This structured setup ensures consistency and alignment with pedagogical outcomes.

3.2 Team Collaboration Features

Team collaboration is a fundamental element of project-based learning, as it cultivates interpersonal communication, accountability, and shared problem-solving. VocaTech integrates tools to support these collaborative processes effectively.

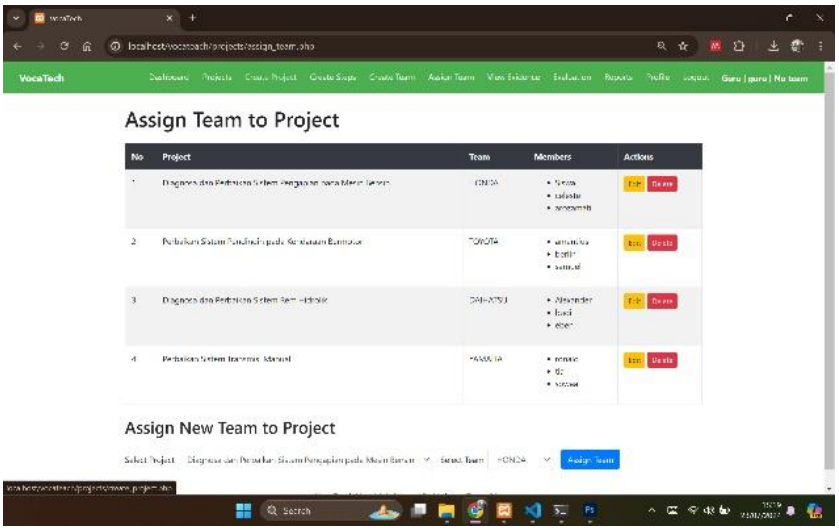

Figure 5. Team Listing Interface

This interface presents a list of all teams created within a project, including team names and assigned student members. Each team's composition is clearly

displayed, helping both students and teachers track participation and coordination within the class.

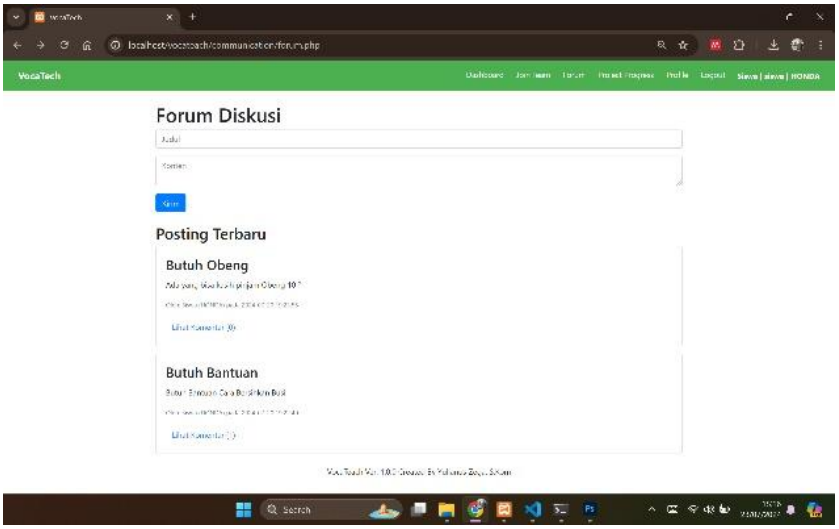

Figure 6. Built-in Discussion Forum

This component enables asynchronous collaboration through topic-specific discussion threads. Students use this forum to pose questions, share findings, and discuss challenges related to their projects. Teachers can also participate to provide guidance and monitor student engagement levels.

3.3 Comprehensive Evaluation System

To ensure a complete assessment process, VocaTech features a multidimensional evaluation system. Teachers can evaluate individual contributions, group performance, and team collaboration using structured rubrics integrated within the platform.

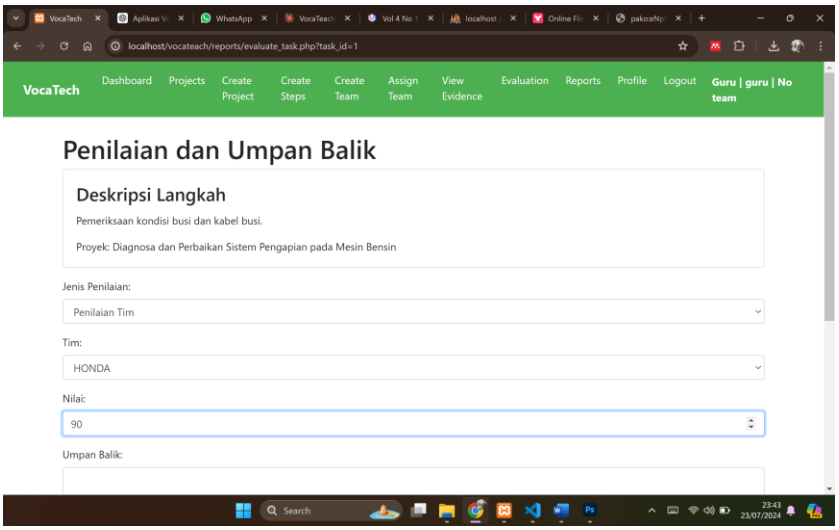

Figure 7. Teacher Evaluation Dashboard

This screen captures the teacher's assessment interface, showing options to assign scores to individual students, entire teams, and collaborative performance. The modular structure allows for transparency and customization in the evaluation process.

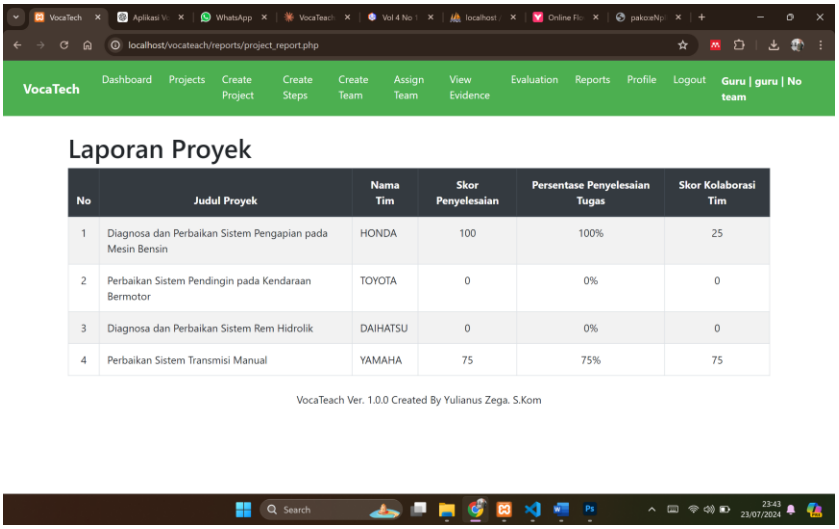

Figure 8. Automatic Project Report Generation

Once a project is completed and evaluated, the system generates a comprehensive report. This report includes details such as project completion rates, individual grades, teamwork scores, and overall feedback. It helps teachers summarize learning outcomes and share them with students or school administrators.

3.4 Data Architecture

To support the system's functionalities, VocaTeach utilizes a well-designed database structure that governs how information is stored, accessed, and related within the platform.

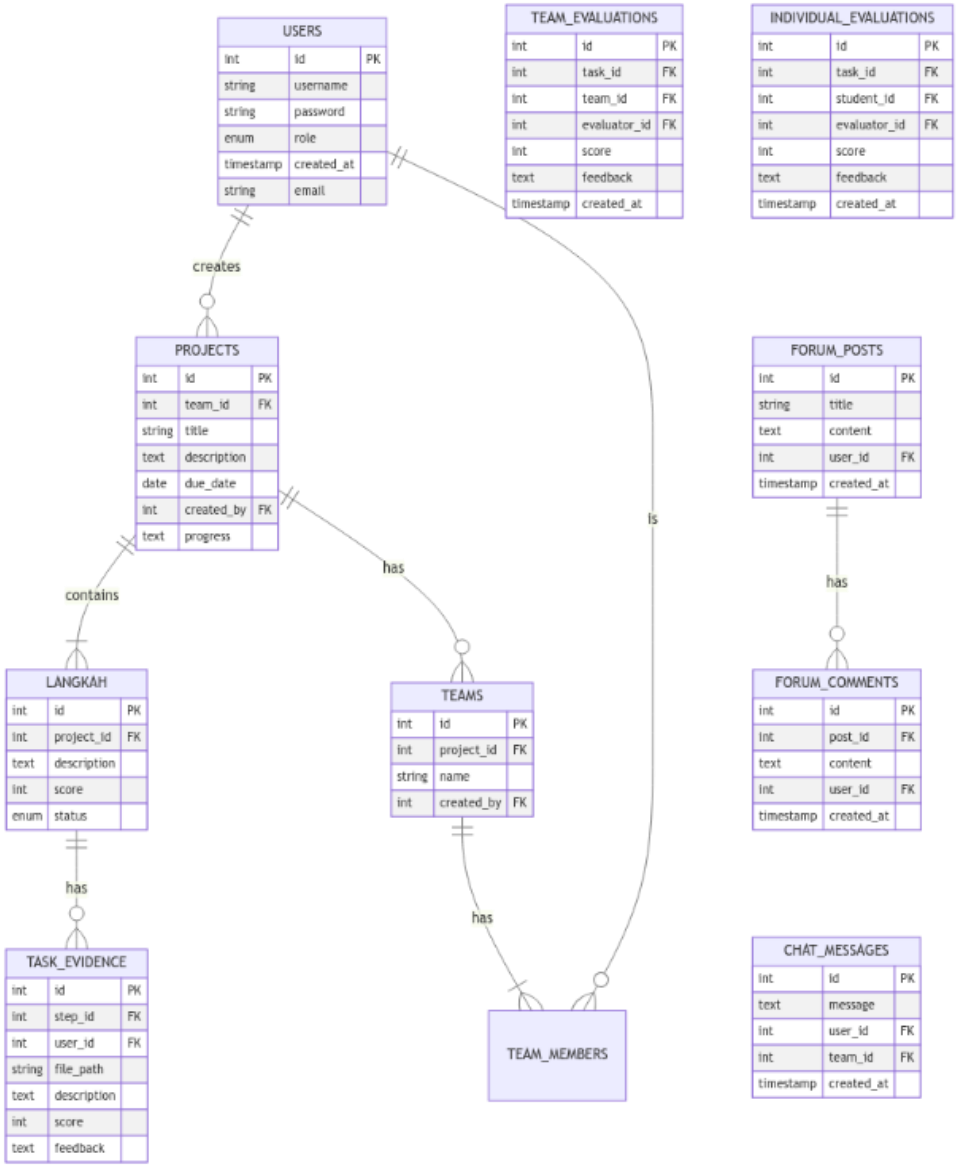

Figure 9. Entity Relationship Diagram (ERD) of VocaTeach

This ERD outlines the relationships among key entities such as Users, Projects, Teams, Tasks, Evaluations, and Discussions. Each entity is connected through primary and foreign keys, ensuring consistency, data normalization, and seamless data retrieval during system use. The diagram reflects the logical foundation supporting the entire platform's backend operations.

3.5 Implementation Outcomes

The initial implementation of VocaTeach at SMK Swasta Pembda Nias yielded significant improvements in several key areas of teaching and learning. The results are presented both quantitatively (in Table 1) and qualitatively, confirming the platform's effectiveness in enhancing vocational education.

Table 1. Summary of Quantitative Outcomes from VocaTeach Implementation

No	Outcome Area	Indicator	Pre-Implementation	Post-Implementation	% Change
1	Student Engagement	Student interest in automotive projects	–	85%	85%
		Weekly project hours	5 hours	7 hours	40%
		Project attendance rate	82%	97%	15%
2	Team Collaboration & Communication	Reported teamwork improvement	–	78%	78%
		Avg. student interactions per project	10 interactions	25 interactions	150%
		Teachers reporting better discussion	–	90%	90%
3	Project Supervision & Evaluation	Teacher time managing projects	10 hours/week	7 hours/week	-30%
		Time for project evaluation	2 hours/project	1.5 hours/project	-25%
		Teachers reporting easier tracking	–	95%	95%
4	Learning Outcomes	Avg. theory test scores	72	85	18%
		Students improved in diagnostics task	–	82%	82%
		Time to complete diagnostic task	–	-20%	-20%

Table 1 summarizes the key indicators measured before and after the implementation of the VocaTeach platform. Substantial improvements were observed across all dimensions. Student engagement increased not only in self-reported interest but also in project time commitment and attendance. Similarly, team communication and collaboration demonstrated remarkable gains, especially in terms of interaction frequency (+150%).

Teacher workload was significantly reduced, with time savings of up to 30% in project management and 25% in evaluation activities. Learning outcomes also improved, as indicated by an 18% increase in theoretical test scores and enhanced performance in diagnostic tasks.

The qualitative data gathered through interviews further reinforce the quantitative findings. One student reflected on their learning experience by stating that "projects feel more engaging and connected to real-life industry problems," highlighting how the platform successfully contextualizes academic content within industry-relevant scenarios. A teacher echoed this sentiment, noting that "students are more proactive and enthusiastic during project activities," which suggests a shift toward greater student ownership and

motivation. Another teacher observed that "student communication has become more structured and productive," indicating that the collaborative tools in VocaTeach foster clearer interaction and more purposeful teamwork. Furthermore, the head of the automotive department emphasized the platform's contribution to assessment integrity by stating, "standardized assessment improves fairness and reduces bias," underscoring the value of systematic, technology-supported evaluation methods in vocational education.

3.6 Comparative Analysis and Interpretation

The outcomes of this study are consistent with findings from prior research, which reported a 15% increase in academic performance and a 22% improvement in practical skills through the implementation of project-based learning applications in vocational schools [5]. However, the current study demonstrates even more substantial impacts, particularly in terms of student interaction, which increased by 150%, and efficiency in teacher workload management, with a 30% reduction in project supervision time (as shown in Table 1).

Statistical analysis further validates these improvements. A Cohen's d value of 0.8 was recorded for the gain in theoretical test scores, which corresponds to a large effect size according to standard benchmarks. Moreover, the results were found to be statistically significant ($p < 0.05$), indicating that the observed changes are not only meaningful in practice but also robust under inferential testing.

As presented in Table 1, the quantitative data reflect significant enhancements in student engagement, collaboration, instructional efficiency, and academic outcomes. These improvements demonstrate that VocaTeach contributes meaningfully to the digital transformation of vocational education. Furthermore, the platform shows strong potential as a scalable and replicable model for similar schools, especially in under-resourced or geographically isolated regions. The combination of improved learning performance and reduced instructional burden supports the continued integration of project-based learning supported by digital tools in vocational settings.

3.7 Discussion

The development and implementation of VocaTeach demonstrated substantial effectiveness in enhancing project-based learning in vocational automotive education. This section discusses the major findings, compares them with existing literature, and outlines theoretical and practical implications.

The integration of a structured project management system enabled teachers to design and oversee complex learning activities aligned with the automotive curriculum. Real-time monitoring and structured task allocation facilitated

better planning and increased accountability, addressing the challenge of fragmented project supervision often found in vocational education. These findings align with previous studies that emphasize the importance of digital scaffolding in project-based learning to support instructional consistency and monitoring [18]–[20].

VocaTeach's collaboration features, including team management tools and built-in discussion forums, promoted meaningful interaction among students. The increase in peer-to-peer communication (+150%) and the 78% improvement in teamwork skills reflect the platform's capacity to support social learning mechanisms, in line with constructivist theories of learning and prior research emphasizing collaborative learning as a driver for skill development in vocational training [21], [22]. Notably, 90% of teachers observed a significant improvement in student discussions, indicating not only higher engagement but also the development of soft skills essential for workplace readiness.

The multidimensional evaluation system offered a flexible and holistic assessment approach, combining individual, group, and collaborative performance metrics. The resulting 25% reduction in teacher evaluation time and improved transparency resonate with the broader discourse on the need for fair and scalable evaluation systems in digital learning environments [23], [24]. Teachers noted increased confidence in the fairness of assessments, and students perceived feedback to be clearer and more structured—both crucial for improving learning outcomes.

From a technological standpoint, the system's back-end architecture—supported by a robust Entity Relationship Diagram (ERD)—ensured stable and reliable data operations, allowing real-time performance tracking and dynamic report generation. This design addressed common challenges in vocational settings, such as poor system responsiveness or fragmented data, which often hinder technology adoption [25], [26].

Quantitative analysis, as presented in Table 1, showed significant improvement in all indicators. Engagement rose by 40%, theoretical scores improved by 18%, and the time required for project supervision decreased by 30%. These improvements not only mirror previous research in project-based learning [5] but also surpass it in areas such as collaborative interaction and systematized project management. Additionally, the large effect size (Cohen's $d = 0.8$) for the increase in theoretical test scores and the statistical significance ($p < 0.05$) reinforce the robustness and validity of these outcomes.

Qualitative data complemented the numeric trends. Students reported heightened enthusiasm and relevance of the projects to real-world problems. Teachers affirmed improved classroom dynamics, more structured student communication, and enhanced efficiency in overseeing multiple projects concurrently [27]–[29]. The head of the automotive department emphasized the

fairness of the evaluation model, which reinforces the importance of transparent digital assessment tools in vocational education [30], [31].

These results suggest that VocaTeach not only supports cognitive development through better understanding and retention of automotive concepts but also fosters critical 21st-century competencies such as collaboration, digital literacy, and problem-solving. This aligns with the broader goals of vocational education in preparing students for industry 4.0 demands.

Importantly, the implementation was conducted in a rural and resource-limited setting (Nias), demonstrating the system's adaptability and scalability. The results support the notion that effective digital transformation is achievable even in geographically challenged areas, provided that tools are appropriately contextualized and designed for user-centered functionality.

In summary, the VocaTeach platform has proven to be a robust instructional innovation, combining pedagogical soundness with technical reliability. Its success reinforces the role of integrated digital platforms in transforming vocational education and offers a replicable model for similar institutions across Indonesia and other developing regions.

4. Conclusion

This study concludes that the development and implementation of VocaTeach, a project-based learning web application tailored for automotive vocational education, has led to substantial improvements in student engagement, collaboration, instructional efficiency, and learning outcomes. The system's features—including structured project management, integrated collaboration tools, and comprehensive evaluation modules—successfully addressed key pedagogical and operational challenges faced by teachers and students in vocational settings.

Quantitative evidence demonstrated significant gains across all indicators: student interest in automotive projects increased by 85%, peer interaction rose by 150%, and teacher workload for supervision and evaluation was reduced by up to 30%. Additionally, theoretical test scores improved by 18%, with statistically significant results ($p < 0.05$) and a large effect size (Cohen's $d = 0.8$). Qualitative feedback further emphasized the platform's ability to foster active learning, teamwork, and fair assessment.

VocaTeach thus offers a replicable model for integrating digital solutions into vocational education, particularly in under-resourced and geographically isolated areas like Nias. It exemplifies how digital platforms can support the transformation of education in alignment with the competencies demanded by Industry 4.0, such as digital literacy, critical thinking, and collaborative problem-solving.

Despite its success, this study has several limitations. First, the implementation was limited to a single vocational school in one region, which may affect generalizability. Second, the system primarily relied on web-based architecture, which might present challenges in areas with poor internet infrastructure. Third, the evaluation focused on short-term outcomes; long-term impacts on employability or career-readiness were not measured.

Future studies should explore longitudinal impacts of platforms like VocaTeach on students' career trajectories and workplace performance. In addition, there is a need to investigate the integration of emerging technologies aligned with Industry 5.0, such as personalized AI tutors, Internet of Things (IoT) for smart labs, and human-centric automation to further enhance vocational learning. Moreover, expanding trials across multiple vocational fields and diverse regional contexts will provide more robust evidence for scalability and national policy adoption.

In conclusion, VocaTeach represents a significant step forward in transforming vocational education for the digital age. Its continued development and integration with 4.0 and 5.0 education paradigms will be crucial in equipping future generations with the skills needed to thrive in a rapidly evolving industrial landscape.

Author's declaration

Author contribution

Yulianus Zega contributed to the conceptualization, supervision, academic guidance, and manuscript revision. He provided critical insights throughout the research process and ensured alignment with vocational education frameworks and contributed to the methodology design, system development, data collection, data analysis, and initial manuscript drafting. He was also responsible for coordinating with the vocational school and validating the implementation of the VocaTeach platform.

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Competing interest

The author declares no competing interests related to the content of this study.

Ethical clearance

This study was conducted in accordance with ethical research guidelines. Ethical approval was obtained from the Research Ethics Committee of Universitas Negeri Padang. All participants provided informed consent prior to involvement in the study.

AI statement

No generative AI tools were used in the analysis, interpretation, or writing of the final version of this manuscript. All findings and content were developed by the author based on original research and validated procedures.

Publisher's and Journal's note

Universitas Negeri Padang as the publisher and Editor of Jurnal Vokasi Informatika state that there is no conflict of interest towards this article publication.

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