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ORIGINAL

Developing and Assessing the Impact of an Integrated STEM Project-Based Learning Model in Vocational Education for Enhanced Competence and Employability

Desarrollo y evaluación del impacto de un modelo integrado de aprendizaje basado en proyectos STEM en la formación profesional para mejorar la competencia y la empleabilidad

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ABSTRACT

The increasing demand for skilled professionals in technical fields such as Industrial Automation Engineering necessitates the implementation of effective teaching methods in vocational education. This study aims to evaluate the effectiveness of an Integrated STEM (Science, Technology, Engineering, and Mathematics) Project-Based Learning (PBL) model in enhancing students' competence and employability at SMK Negeri 1 Pariaman. Employing a quasi-experimental Nonequivalent Control Group Design, the research involved 60 students divided equally into an experimental group and a control group. The experimental group received instruction through the integrated STEM-PBL approach, while the control group followed conventional teaching methods. Data were collected using pre- and post-tests, as well as qualitative surveys and interviews, to assess students' academic performance, learning engagement, and perceptions of the educational experience. The findings revealed that students exposed to the STEM-PBL model showed significant improvements in both theoretical knowledge and practical skills, outperforming those in the control group. Additionally, qualitative data indicated that the STEM-PBL approach fostered greater student engagement, motivation, and the development of critical 21st-century skills, such as critical thinking, problem-solving, and teamwork, which are essential for success in the industrial workforce. The study concludes that integrating STEM principles with project-based learning substantially enhances vocational students' readiness for employment by providing both cognitive and non-cognitive competencies. It recommends broader implementation of this model within vocational institutions. Future research is encouraged to explore the integration of emerging technologies to further strengthen the impact of project-based learning in technical and vocational education settings.

Keywords: STEM Project-Based Learning; Vocational Education; Industrial Automation Engineering.

RESUMEN

La creciente demanda de profesionales cualificados en campos técnicos como la Ingeniería de Automatización Industrial hace necesaria la aplicación de métodos de enseñanza eficaces en la formación profesional. El objetivo de este estudio es evaluar la eficacia de un modelo integrado de aprendizaje basado en proyectos (ABP) de STEM (ciencia, tecnología, ingeniería y matemáticas) para mejorar la competencia y la empleabilidad de los estudiantes en SMK Negeri 1 Pariaman. Empleando un diseño cuasiexperimental de grupo de control no equivalente, en la investigación participaron 60 estudiantes divididos a partes iguales en un grupo experimental

y un grupo de control. El grupo experimental recibió instrucción a través del enfoque integrado STEM-PBL, mientras que el grupo de control siguió los métodos de enseñanza convencionales. Se recogieron datos mediante pruebas previas y posteriores, así como encuestas y entrevistas cualitativas, para evaluar el rendimiento académico de los estudiantes, su compromiso con el aprendizaje y su percepción de la experiencia educativa. Los resultados revelaron que los estudiantes expuestos al modelo STEM-PBL mostraron mejoras significativas tanto en conocimientos teóricos como en habilidades prácticas, superando a los del grupo de control. Además, los datos cualitativos indicaron que el enfoque STEM-PBL fomentó un mayor compromiso y motivación de los estudiantes, así como el desarrollo de habilidades críticas del siglo XXI, como el pensamiento crítico, la resolución de problemas y el trabajo en equipo, que son esenciales para el éxito en la mano de obra industrial. El estudio concluye que la integración de los principios STEM con el aprendizaje basado en proyectos mejora sustancialmente la preparación de los estudiantes de formación profesional para el empleo al proporcionarles competencias cognitivas y no cognitivas. Se recomienda una aplicación más amplia de este modelo en los centros de formación profesional. Se anima a la investigación futura a explorar la integración de las tecnologías emergentes para fortalecer aún más el impacto del aprendizaje basado en proyectos en entornos de educación técnica y profesional.

Palabras clave: Aprendizaje Basado en Proyectos STEM; Formación Profesional; Ingeniería de Automatización Industria.

INTRODUCTION

Vocational education plays a vital role in bridging the gap between formal education and industry by equipping students with essential theoretical and practical skills necessary for career readiness.[1] In response to the evolving demands of the labor market, vocational curricula must continuously adapt, with increasing emphasis placed on integrating STEM (Science, Technology, Engineering, and Mathematics) to foster students' critical thinking and problem-solving abilities.[2] This integration is seen as essential for aligning education with industry needs, especially as technological advancements reshape the nature of work. Scholars argue that vocational institutions should not only respond to current skill gaps but also anticipate future demands through proactive curriculum development, incorporating real-world training such as internships to strengthen employability.[3,4]

The emergence of the Fourth Industrial Revolution (4IR) further underscores the urgency for innovative and responsive vocational education. In this context, integrating STEM into vocational training supports the development of multidisciplinary competencies and promotes collaboration between educational institutions and industry partners. Research shows that such integration leads to deeper conceptual understanding and better prepares students for technology-driven careers.[5,6] To achieve this, vocational education must also implement effective teaching strategies, including the use of interactive tools like Arduino and Python programming, which enhance engagement and interest in STEM. These innovations not only modernize the learning process but also empower students to become active participants in their education, ready to meet the complex challenges of the modern workforce.[7,8]

Project-Based Learning (PBL) has gained prominence as an effective pedagogical approach, particularly in vocational education, due to its emphasis on real-world problem-solving and active student engagement.[9,10] Unlike traditional lecture-based methods, PBL enables learners to apply theoretical concepts through practical projects, simultaneously developing essential soft skills such as communication, teamwork, and time management.[11] Research supports its effectiveness in fostering critical thinking, adaptability, and collaboration—skills increasingly valued in the modern workforce. Furthermore, PBL encourages innovation and creativity by challenging students to devise solutions to complex, authentic problems relevant to their future careers.[12]

In addition to cognitive gains, PBL also promotes social and personal competencies. Surveys indicate that a majority of students report improvements in skills such as teamwork and critical thinking, with around 88 % recognizing its value for personal development.[13,14] These outcomes are further enhanced when PBL is integrated with technology, allowing students to collaborate via digital platforms and access diverse learning resources. The COVID-19 pandemic highlighted PBL's flexibility, as it effectively transitioned to online formats while maintaining its focus on interactive, student-centered learning.[15,16] This adaptability reinforces the relevance of PBL in preparing students for the digital demands of contemporary and future work environments, where both technical proficiency and digital literacy are essential.[17]

Integrating STEM (Science, Technology, Engineering, and Mathematics) into Project-Based Learning (PBL) in vocational education offers a transformative approach that bridges theoretical knowledge with practical application.[3,18] This integration fosters a multidisciplinary learning environment where students develop the

ability to synthesize scientific principles, apply engineering processes, use technological tools, and utilize mathematical reasoning. Such a cohesive framework mirrors real-world workplace scenarios and enhances students' problem-solving capabilities. Authentic experiences—such as using technology for hands-on tasks—not only reinforce technical skills but also build critical thinking and adaptability, making students better prepared for careers in sectors like manufacturing, IT, and engineering.[19,20]

Moreover, STEM-PBL promotes collaboration, creativity, and communication—skills that are essential in modern employment contexts.[21] Research indicates that vocational students who engage in STEM-based projects demonstrate improved mastery of both academic concepts and practical skills. This alignment with industry needs is further reinforced by policies like "Link and Match," which ensure that vocational curricula stay relevant to labor market demands.[3,22] Studies also show that integrating STEM with PBL enhances student motivation and interest in STEM careers. Ultimately, this approach strengthens the relevance of vocational education by offering real-world context, empowering students to apply their learning effectively, and guiding institutions in designing future-ready curricula that meet both student and industry expectations.[18,23]

The integration of STEM education within a Project-Based Learning (PBL) framework presents great potential for enhancing vocational education, particularly in preparing students for future careers. While its theoretical benefits are well acknowledged, there is a notable lack of rigorous empirical evaluation regarding its actual impact on learning outcomes, such as skill development, problem-solving ability, and workforce readiness.[24] Studies have indicated that STEM-PBL promotes critical and creative thinking, especially through hands-on, meaningful learning experiences. This approach aligns well with the demands of modern industries by enabling students to solve real-world problems, fostering both technical and soft skills essential for employability.[25]

In vocational contexts, STEM-PBL supports deeper engagement and learning when applied in motivating and realistic scenarios. Research underscores the importance of assessment tools capable of capturing interdisciplinary competencies and guiding curriculum refinement.[26] Despite the developmental stage of such tools, their use is vital for ensuring that educational practices stay aligned with evolving labor market needs. Evidence also shows that students involved in integrated STEM-PBL programs tend to demonstrate stronger problem-solving skills and greater interest in STEM careers.[27] As vocational education continues to adapt to industrial transformations, continuous assessment and curriculum adjustments based on student outcomes become essential for sustaining relevance and effectiveness in a rapidly changing workforce landscape.[28]

The increasing importance of STEM competencies in today's workforce has made it imperative for vocational education to adopt instructional models that not only build technical knowledge but also cultivate critical soft skills such as collaboration, communication, and adaptability.[29] The integration of STEM within Project-Based Learning (PBL) frameworks is a promising response to this need, offering a student-centered approach that emphasizes hands-on, real-world problem-solving.[30] By combining theoretical instruction with practical application, the integrated STEM-PBL model creates authentic learning experiences that mirror workplace demands. This approach directly responds to industry expectations for graduates who are not only technically proficient but also capable of navigating complex, interdisciplinary tasks.[31]

This study is driven by the necessity to empirically assess the effectiveness of the integrated STEM-PBL approach in vocational education settings. While existing literature highlights the benefits of STEM and PBL individually, few studies have examined their combined impact on vocational students' competencies and employability.[32] The research particularly focuses on how this model influences academic engagement, mastery of technical content, and the development of essential 21st-century skills.[33,34] Furthermore, the study seeks to understand how project-based tasks aligned with industry scenarios contribute to students' readiness for employment. By examining these outcomes, the study aims to fill the gap in empirical data that supports evidence-based improvements to vocational education curricula.[35,36]

The primary objective of this study is to evaluate the impact of implementing an integrated STEM-PBL instructional model on students' competence and workforce readiness at SMK Negeri 1 Pariaman. The research specifically compares learning outcomes between students exposed to the STEM-PBL model and those receiving traditional instruction. Through quantitative and qualitative measures, the study seeks to determine whether the integrated model significantly enhances theoretical understanding, practical skills, and soft skill development. The findings are expected to provide valuable insights for educators and policymakers, justifying the broader adoption of STEM-PBL in vocational institutions to ensure that graduates are well-equipped to meet the dynamic and evolving needs of the labor market.

METHOD

Research Design

This study utilizes a Nonequivalent Control Group Design, categorized under Quasi-Experimental Design. This design was selected as it aligns with the research objectives of assessing the impact of an integrated STEM Project-Based Learning (PBL) model in vocational education, particularly focusing on the enhancement of students' competence and employability. The Quasi-Experimental Design, as an extension of the True

Experimental Design, is considered more suitable than Pre-Experimental Design for comparing the outcomes between the experimental and control groups under different teaching approaches in a vocational education context.[37]

In this study, two groups of students are involved: the experimental group, which receives the integrated STEM-PBL treatment, and the control group, which follows traditional teacher-centered learning methods. The research subjects consist of students enrolled in the SMK Negeri 1 Pariaman, specifically in the Industrial Automation Engineering course. Each group comprises 30 students. The study will span over several sessions, with the experimental and control groups following distinct learning procedures.

Table 1. Research Design

Group	Pre-Test	Treatment (X)	Post-Test
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Explanation:

O_1 & O_3: Pretest observation for the experimental and control group.
X: The treatment or intervention given to the experimental group
O_2 & O_4: Posttest observation for the experimental and control group.

Hypothesis

The primary hypothesis of this study is as follows:

a) H1: The implementation of the integrated STEM Project-Based Learning (PBL) model in the Industrial Automation Engineering course at SMK Negeri 1 Pariaman leads to a significant improvement in students' competence and employability compared to the traditional teacher-centered learning method used in the control group.

b) H0: The implementation of the integrated STEM Project-Based Learning (PBL) model in the Industrial Automation Engineering course at SMK Negeri 1 Pariaman does not lead to a significant improvement in students' competence and employability compared to the traditional teacher-centered learning method used in the control group.

Data Collection Instrument

The instruments for data collection in this study incorporate both quantitative and qualitative methods to provide a comprehensive evaluation of the effectiveness of the integrated STEM Project-Based Learning (PBL) model in vocational education. Quantitative data will be collected through pre- and post-assessments designed to measure students' competence in Industrial Automation Engineering, focusing on their theoretical understanding and practical application of STEM-related concepts. The pre-test will be administered prior to the implementation of the integrated STEM-PBL model, while the post-test will be conducted after the intervention to assess improvements in learning outcomes and employability skills.

In addition, practical performance evaluations will be carried out to assess students' abilities in applying STEM knowledge to real-world industrial automation tasks. These assessments will emphasize skills such as project planning, problem-solving, technical execution, and teamwork in practical settings. Students will also complete structured surveys using Likert scales to gauge their engagement, motivation, and perceptions regarding the integrated STEM-PBL approach. The surveys aim to capture students' experiences with collaborative learning, skill development, and overall satisfaction with the learning model.

Qualitative data will be gathered through semi-structured interviews with both students and instructors. These interviews will explore participants' insights and experiences related to the integrated STEM-PBL model, emphasizing aspects such as collaboration, critical thinking, problem-solving, and the model's contribution to employability readiness. This qualitative data will complement the quantitative results from assessments and surveys, offering a richer, more holistic understanding of the model's impact on vocational students' competence and readiness for the workforce.

Data Analysis Techniques

The data analysis in this study employs both quantitative and qualitative methods to evaluate the effectiveness of the integrated STEM Project-Based Learning (PBL) model in the Industrial Automation Engineering course at SMK Negeri 1 Pariaman. The study involves two groups: the experimental group, consisting of 30 students, which receives the integrated STEM-PBL treatment, and the control group, also consisting of 30 students, which follows traditional teacher-centered learning methods. For the quantitative analysis, statistical techniques such as descriptive statistics and inferential statistics will be utilized. Pre- and post-test scores from both

groups will be compared using independent t-tests or analysis of variance (ANOVA) to determine whether there is a significant difference in competence, practical skills, and employability-related learning outcomes between the two groups. It is expected that the experimental group will demonstrate greater improvement in critical thinking, problem-solving, and technical skills compared to the control group.

In addition to quantitative data, qualitative data will be collected through surveys and semi-structured interviews. These qualitative responses will be analyzed using thematic analysis to identify recurring patterns and themes related to student engagement, motivation, collaboration, and perceptions of the integrated STEM-PBL learning process. This mixed-methods approach will provide a richer and more comprehensive understanding of the impact of the model on students' learning experiences and their readiness for employment. This detailed evaluation will enable a thorough assessment of the integrated STEM-PBL model's effectiveness in enhancing both competence and employability among vocational education students, thereby contributing valuable insights for curriculum development and teaching practices in similar educational contexts.

RESULT

STEM Project-Based Learning Model Approach

The STEM Project-Based Learning (PBL) approach developed in this study integrates core principles of Science, Technology, Engineering, and Mathematics into a cohesive instructional model tailored for vocational education, specifically within the Industrial Automation Engineering curriculum at SMK Negeri 1 Pariaman. This approach emphasizes student-centered learning through collaborative projects that simulate real-world industrial problems, thereby fostering critical thinking, creativity, and technical competence. The model's design follows the ADDIE framework, incorporating iterative analysis, design, development, implementation, and evaluation phases to ensure alignment with both educational standards and industry needs.

Figure 1. STEM Project-Based Learning Handbook

Implementation of the STEM PBL approach involves structured learning stages, including problem identification, project planning, execution, monitoring, and reflection. Students work in teams to tackle authentic industry-relevant challenges, encouraging active engagement and peer collaboration. The use of hands-on activities, supported by detailed teaching guides, student modules, and multimedia instructional resources, facilitates the integration of theoretical STEM concepts with practical skills. Additionally, the model incorporates continuous assessment through formative and summative evaluations to monitor student progress and project outcomes, enabling timely feedback and adaptive teaching strategies.

The results indicate that the STEM PBL approach significantly enhances students' cognitive, affective, and psychomotor competencies, contributing to improved competence and employability. Students demonstrated greater mastery of industrial automation principles, increased problem-solving abilities, and better teamwork skills compared to those taught via traditional methods. Furthermore, the approach fostered positive attitudes towards learning and heightened motivation, as evidenced by both quantitative assessments and qualitative feedback from students and instructors. These findings support the adoption of integrated STEM PBL models as an effective pedagogical strategy in vocational education to prepare students for the demands of the modern

workforce.

Data Analysis and Findings

The data analysis conducted in this study demonstrates significant improvements in student learning outcomes following the implementation of the integrated STEM Project-Based Learning (PBL) model in the Industrial Automation Engineering course at SMK Negeri 1 Pariaman. Both quantitative and qualitative data were collected, with pre- and post-tests serving as the primary instruments to measure students' competence, practical skills, and employability-related attributes. Descriptive and inferential statistical analyses, including independent sample t-tests, were applied to compare the performance of the experimental group, which experienced the integrated STEM-PBL approach, with the control group, which followed traditional teacher-centered instruction. The experimental group exhibited substantial gains in critical thinking, problem-solving, and the application of STEM concepts to practical industrial automation tasks, while the control group showed comparatively modest improvements.

Further analysis of qualitative data obtained through surveys and interviews revealed positive student and instructor perceptions of the integrated STEM-PBL model. Participants reported enhanced engagement, motivation, and collaboration during the learning process, contributing to a deeper understanding of complex vocational concepts and better preparation for the workforce. The combined findings from both quantitative and qualitative analyses confirm that the integrated STEM Project-Based Learning model is effective in improving vocational students' competence and employability, thereby offering a more relevant and dynamic educational experience compared to conventional teaching methods.

Table 2. Results of the Descriptive Analysis Results for Pre-Test and Post-Test

Group	Mean Pre-Test Score	Mean Post-Test Score
Experiment	32,68	79,88
Control	31,72	75,95

The table displays the descriptive analysis results of pre-test and post-test scores for the experimental and control groups in a study focused on developing and assessing the impact of an Integrated STEM Project-Based Learning model in vocational education. The experimental group started with a mean pre-test score of 32,86 and improved significantly to a mean post-test score of 79,88 after the intervention. Meanwhile, the control group, which followed conventional teaching methods, had a slightly lower mean pre-test score of 31,72 and achieved a post-test mean score of 75,95. The notable increase in the experimental group's scores indicates that the integrated STEM Project-Based Learning model effectively enhances student competence and readiness for employability in vocational education, surpassing traditional instructional approaches in fostering both knowledge acquisition and practical skill development. Furthermore, the normality test was applied to determine the suitability of the data to inferential tests regarding the degree to which it was normally distributed. The results of the Shapiro-wilk test were used to determine the distribution of the data.

Table 3. Results of the Shapiro-wilk Test

Group	Pre-Test (p-value)	Post-Test (p-value)
Experiment	0,050	0,342
Control	0,616	0,238

The results show that the data in both groups, for both pre-test and post-test, were normally distributed ($p > 0,05$). Levene's Test was used to examine the homogeneity of variances between the experiment and control groups.

Table 4. Results of Levene's Test

Variable	F	Sig. (p-value)
Post-Test	0,010	0,919

The analysis indicates that the variances of the experiment group to the control group were similar ($p > 0,05$) suggesting that the groups could be compared parametrically. To establish the researching hypothesis the two condition Independent Sample T-Test was used to compare the post test results between the experimental and control groups.

Table 5. Results of T-Test

Test Type	Variable	t	Sig. (p-value)	Interpretation
Independent Sample T-Test	Pre-Test vs Post-Test	1,761	0,024	The experimental group achieved a higher mean post-test score than the control group

The table presents the results of an Independent Sample T-Test conducted to compare the pre-test and post-test scores of the experimental and control groups. The t-value of 1,761 and a significance level (p-value) of 0,024 indicate a statistically significant difference between the groups. Specifically, the experimental group, which experienced the integrated STEM Project-Based Learning intervention, achieved a higher mean post-test score than the control group that followed traditional teaching methods. This result demonstrates that the integrated STEM project-based approach effectively improves student competence and employability skills in vocational education settings, confirming the model's positive impact on learning outcomes.

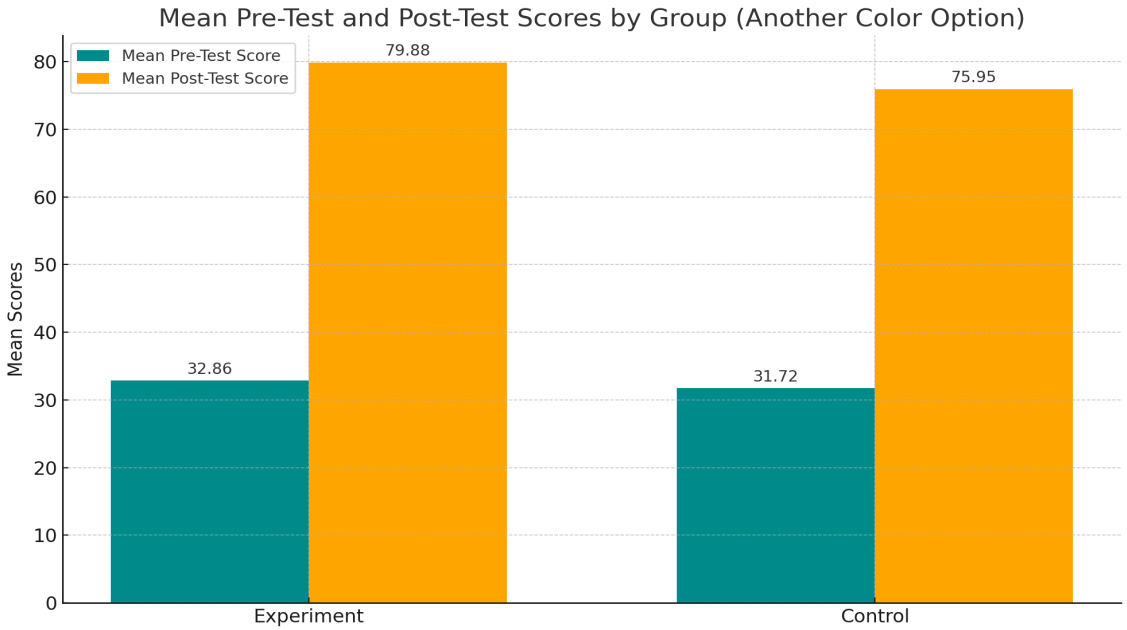

Figure 2. Pre-Test and Post-Test Scores Bar Chart

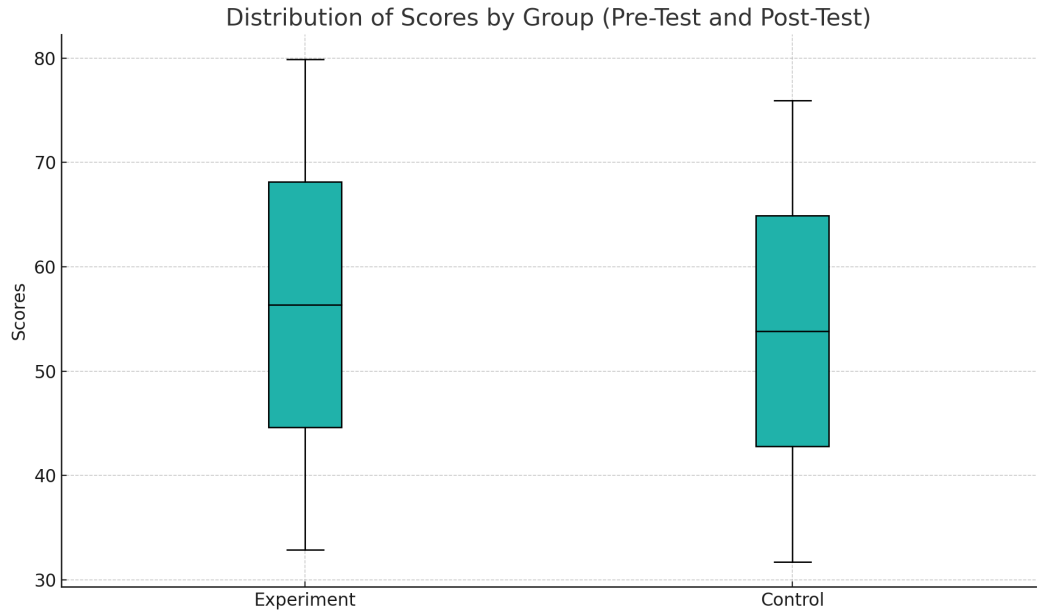

Figure 3. Box Plot Pre-Test and Post-Test Scores

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The boxplot illustrates the distribution of pre-test and post-test scores for both the experimental and control groups. The experimental group exhibits a higher median score and a narrower interquartile range compared to the control group, indicating more consistent and improved performance following the intervention. The control group shows a wider range of scores and a lower median, suggesting greater variability in learning outcomes. These results visually support the quantitative findings that the integrated STEM Project-Based Learning model positively influences student competence and employability skills by enhancing knowledge retention and practical application more effectively than traditional instructional methods.

DISCUSSION

The integration of STEM (Science, Technology, Engineering, and Mathematics) principles within vocational education, particularly through Project-Based Learning (PBL), has proven to significantly enhance students' competence and employability. The findings of this study corroborate the claims made in prior research regarding the effectiveness of STEM-based learning approaches in vocational settings. As indicated by Feng and Hou[2], the increasing demands of the labor market necessitate that vocational education systems evolve by integrating STEM disciplines to foster critical thinking and problem-solving skills that are highly valued by employers.

This study's results align with the work of Jalinus[9], who highlighted that Project-Based Learning enhances students' problem-solving abilities by engaging them in real-world projects. The experimental group in this study, which received STEM-PBL interventions, demonstrated substantial improvements in their competencies related to industrial automation, surpassing the control group, which followed traditional methods. This improvement is consistent with findings from Oriza[10], where students engaged in project-based learning demonstrated better application of theoretical knowledge to practical tasks.

A significant factor contributing to the success of the STEM-PBL model in this study is the active engagement of students in hands-on, collaborative learning experiences. Research by Hanif[20] suggests that such involvement in real-world projects enhances both the technical and soft skills of students, making them more employable. The experimental group, through teamwork and collaboration on authentic industry-relevant challenges, was able to develop stronger teamwork and communication skills, which are critical for success in the workforce.

Additionally, the use of integrated STEM in PBL models fosters a deeper understanding of interdisciplinary concepts. As Kartini[26] emphasize, the integration of various STEM fields in vocational education provides students with a holistic understanding of their disciplines, which is essential for modern problem-solving in industry settings. In this study, students in the experimental group were able to apply concepts from science, technology, engineering, and mathematics in their projects, demonstrating the practical relevance of their learning.

The positive shift in student performance following the implementation of the STEM-PBL approach can also be attributed to the interactive nature of the learning model. The findings from the quantitative data analysis in this study support the conclusion that active learning methods, such as those employed in PBL, are more effective than traditional teaching methods in improving student learning outcomes. This is in line with the conclusions of Jannah [24], who found that PBL significantly enhanced students' critical thinking abilities and fostered a deeper understanding of the subject matter.

Moreover, the increase in student motivation and engagement observed in this study is consistent with the results of research by Muliyati[22], who found that project-based learning approaches, particularly those that incorporate real-world problems, tend to increase student interest and commitment to their studies. The experimental group in this study reported higher levels of engagement and motivation compared to the control group, underscoring the potential of PBL to sustain student interest and enhance their learning experiences.

One of the key advantages of the STEM-PBL model is its ability to prepare students for the challenges of the modern workforce. According to Syamsidah[13], employers are increasingly looking for individuals who possess not only technical skills but also the ability to work collaboratively and solve complex problems. The results of this study demonstrate that the STEM-PBL approach is effective in cultivating both these hard and soft skills, as evidenced by the improved problem-solving abilities and teamwork skills of the experimental group.

The results of this study also highlight the importance of ongoing assessment in the PBL process. Continuous formative and summative evaluations, as utilized in this study, enable educators to provide timely feedback and make necessary adjustments to improve student outcomes. This aligns with the findings of Guzey[25], who emphasize the role of assessment in optimizing the effectiveness of PBL by ensuring that learning objectives are met and students are adequately prepared for real-world challenges.

From a methodological perspective, the use of both quantitative and qualitative data collection methods in this study provides a comprehensive evaluation of the effectiveness of the STEM-PBL model. The integration of surveys, pre- and post-assessments, and semi-structured interviews allows for a more holistic understanding of how students perceive the learning process and its impact on their skills and employability. This approach echoes the recommendations of Creswell[37], who advocates for mixed-methods research in educational settings

to capture a broad spectrum of student experiences.

Finally, the findings of this study underscore the potential of the integrated STEM-PBL model to bridge the gap between education and industry needs. The positive outcomes observed in the experimental group support the notion that vocational education curricula must continue to adapt to the demands of the modern workforce. As highlighted by Kartini[26], the integration of STEM with vocational education equips students with the necessary skills to thrive in a rapidly evolving job market. The success of this approach in the Industrial Automation Engineering course at SMK Negeri 1 Pariaman provides valuable insights for educators and policymakers seeking to enhance the relevance and impact of vocational education.

CONCLUSION

This study concludes that the integrated STEM Project-Based Learning (PBL) model is an effective instructional approach for enhancing student competence and employability in vocational education, particularly within the context of Industrial Automation Engineering. By comparing outcomes between students exposed to the STEM-PBL model and those taught through traditional methods, the research demonstrates that STEM-PBL significantly improves both theoretical understanding and practical skills. It also fosters critical thinking, problem-solving, collaboration, and student engagement—competencies essential for adapting to industry demands. These findings confirm the study's objective by providing empirical evidence that STEM-PBL not only aligns vocational training with labor market needs but also prepares students more effectively for real-world challenges. Therefore, the adoption of innovative, interdisciplinary teaching strategies such as STEM-PBL should be considered a strategic priority in vocational curriculum development. Future studies are recommended to explore the integration of emerging technologies and further refinement of PBL models to enhance their effectiveness across broader vocational contexts.

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