



Designing an Industry-Oriented Problem-Based Learning Model to Enhance Vocational High School Students' Work Readiness

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Abstract

Industry-Oriented Problem-Based Learning Model (I-ProBL) was developed to address the work readiness of vocational high school graduates that are not fully aligned with industry needs. Despite various curriculum reforms and vocational training programs, there remains a significant gap between the competencies acquired by students in school and the practical skills demanded by the industrial sector. Many vocational high school graduates struggle to adapt to real-world work environments due to the lack of exposure to authentic, industry-relevant problem-solving experiences during their education. This study aims to develop and test the effectiveness of the I-ProBL model in improving the skills of vocational high school students. The model used is Research and Development (R&D) with the ADDIE model consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation. The subjects of the study were 270 students, 6 teachers, 3 industry practitioners, and 2 vocational education experts in three vocational high schools in Yogyakarta. The object of this study is the I-ProBL learning model applied in the vocational high school curriculum. Data collection techniques were carried out through interviews, validation questionnaires, and tests. The instruments used included interview grids, model feasibility validation questionnaires, and student practice test instruments. Data analysis was carried out descriptively quantitatively by calculating the average value and percentage of student skill improvement before and after the implementation of the I-ProBL model. The results showed that the I-ProBL model has a high level of suitability with industry needs (4.6, very good category) and relevance to the world of work (4.7, very good category). The implementation of this model increased the average student grades by 20.1% to 21.2% and increased student engagement in learning (85%) and their readiness to face the world of work (90%). The impact of this study shows that I-ProBL can be an effective solution in improving the quality of vocational school graduates and strengthening the relationship between schools and industry. However, for more optimal implementation, it is necessary to improve teacher training, provide more adequate facilities, and support policies that encourage closer collaboration between vocational schools and the industrial world.

Keywords:

Industry-Oriented Problem-Based Learning Vocational Education, Industry, Work Readiness

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INTRODUCTION

Vocational education plays an important role in preparing the industrial workforce, but many vocational high school graduates still have difficulty getting



jobs that match their skills (Lv et al., 2022; Michaelis & Findeisen, 2022; Sakdapat, 2024). The gap between the skills taught in schools and the needs of industry is a major challenge that needs to be addressed (Börner et al., 2018; Groeneveld et al., 2022; Rodzalan et al., 2022). Problem Based Learning (PBL) is known to be effective in improving critical thinking and problem-solving skills. However, its application in vocational high schools is still based on academic scenarios that are less relevant to the industrial world (Börner et al., 2018; Hariani et al., 2023). As a result, many students are less prepared to face real work challenges.

As a solution, Industry-based Problem Based Learning (I-ProBL) integrates PBL models with real experiences from the industrial world. For example, electrical engineering students not only learn theory, but also work on electrical system improvement projects in partner companies. With this approach, students' skills become more relevant to industry needs (Finnveden & Schneider, 2023; Rahayu et al., 2024). I-ProBL emerged as a response to industry complaints that vocational high school graduates still lack problem-solving and teamwork skills (Hidayatulloh & Ashoumi, 2022; Rahayu et al., 2024; Riska Dwi Anggraini et al., 2022). For example, in the manufacturing sector, many graduates have difficulty solving production problems without clear direction from their superiors.

For industry, I-ProBL is also useful in reducing the cost of training new workers. In the automotive industry, for example, many vocational high school graduates are not yet familiar with the lean manufacturing system, so they need a long adaptation time (Gallagher et al., 2020; Naranjo et al., 2020). The implementation of I-ProBL allows industry to play an active role in forming a more ready-to-use workforce (Ashraf et al., 2017; Gerschewski et al., 2020; Sharma et al., 2024). In addition to increasing work readiness, I-ProBL can also increase the learning motivation of students who often feel bored with conventional learning models. For example, graphic design students can work on real projects such as designing marketing materials for partner companies, so they can better understand the application of their skills (Groulx et al., 2024; Orieno et al., 2024; Pop et al., 2023).

However, the implementation of I-ProBL faces challenges, especially in the readiness of teachers who are still accustomed to conventional models and have minimal industry experience (Afriani et al., 2023; Aslam et al., 2023; Du et al., 2022). Therefore, training is needed for teachers so that they can guide students in solving problems that actually occur in the world of work. Support from industry and government is also important to ensure access for vocational schools to the world of industry, especially for schools in remote areas (Alferez-Pastor et al., 2023; Saengrith et al., 2022; Silva et al., 2023). Not all vocational schools have industry partners who can support real project-based learning. Policies that encourage collaboration between vocational schools and industry need to be strengthened so that I-ProBL can be widely implemented (Abdurrahman et al., 2022; Amante & Fernandes, 2023; Liu, 2022; Van Nguyen et al., 2022).

Studies from other countries also show the success of industrial project-based learning approaches. In Germany, a dual vocational training system that combines learning in schools and hands-on training in companies has been shown to be effective in improving graduates' work readiness (Hoidn & Šťastný, 2023). In China, collaborative programmes between vocational schools and the

manufacturing sector are used to develop skills needed in high-tech industries (Song & Xu, 2024). Meanwhile, in Australia, a Work-Integrated Learning (WIL) approach is implemented to ensure students gain real industry experience during their studies (Jackson, 2018). These studies show that the global implementation of I-ProBL can be adapted to the local context while still referring to the principle of direct industry involvement in the learning process.

Nevertheless, international studies also highlight challenges similar to those faced in Indonesia. Simon and Zeng (2024) reported that vocational teachers in China often resist I-ProBL implementation due to lack of industrial experience and unfamiliarity with project-based approaches (Simon & Zeng, 2024). Similarly, Schwede et.al (2025) noted that in Germany, cultural and institutional inertia in schools hinders the full adoption of work-based learning (Schwede et al., 2025). In Australia, Montt-Blanchard et al. (2023) emphasized the difficulty in sustaining long-term partnerships between industry and schools, which affects the continuity of workplace learning experiences. These findings underscore the need for systemic support, including teacher training, curriculum flexibility, and strong industry-school collaboration frameworks (Montt-Blanchard et al., 2023).

In addition, one possible weakness of the I-ProBL model is the dependency on the availability and quality of industry partners. If industries are not willing or ready to be involved, the model cannot run optimally. Another concern is the potential inequality among schools; schools in urban areas with better access to industries may implement I-ProBL more successfully than those in rural or remote regions, which could widen the gap in educational quality and work readiness (Çınar et al., 2021; Govindan & Arampatzis, 2023). Moreover, without continuous supervision and alignment of project content with learning outcomes, students may focus more on task completion rather than competency development.

I-ProBL is not just a learning innovation, but a strategy to improve the competitiveness of the Indonesian workforce. The high unemployment rate of vocational school graduates shows the need to align skills with industry needs (Mada Aditia Wardhana et al., 2023; Rahayu et al., 2024). With this model, graduates are better prepared to face work challenges and reduce unemployment rates. The implementation of I-ProBL needs to be supported by various parties so that it can run effectively and sustainably. Thus, vocational school graduates will be more competitive in the modern industrial era (Amante & Fernandes, 2023; Liu, 2022; Mada Aditia Wardhana et al., 2023; Mahmudah et al., 2022; Van Nguyen et al., 2022).

The purpose of this study is to develop and test the effectiveness of Industry-based Problem Based Learning (I-ProBL) model in improving vocational students' work readiness through the integration of real industry project-based learning. The research questions posed in this study include: (1) How is the design of the I-ProBL model that can be effectively implemented in the SMK environment? (2) To what extent can the I-ProBL model improve problem solving, collaboration, and work readiness skills of vocational students? (3) What are the supporting and inhibiting factors in implementing the I-ProBL model in vocational schools?

The significance of this research is to contribute to the development of vocational education policy in Indonesia by providing a learning model that is more relevant to industry needs. In addition, this research is also expected to be a

reference in teacher training and industrial experience-based curriculum design that can improve the competitiveness of SMK graduates in the modern industrial era.

METHODS

This study uses the Research and Development (R&D) model with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model to design and evaluate the I-ProBL learning model. The Analysis stage identifies the gap between vocational high school students' skills and industry through interviews. Design includes designing learning scenarios and validation instruments. Development produces learning tools such as modules and expert evaluations. Implementation is carried out in three vocational high schools with model trials. Evaluation assesses effectiveness based on student tests, model validation, and feedback from teachers and industry.

This research involved 6 teachers, 3 industry practitioners, 2 vocational education experts, and 270 students from three vocational schools in Yogyakarta, as well as collaborating with the automotive industry. Data collection techniques included interviews, validation questionnaires, and tests to measure the improvement of students' skills before and after the implementation of I-ProBL. The research data collection instruments used can be seen in Table 1, Table 2 and Table 3. The results of the interviews were analysed descriptively with percentages, i.e. by grouping respondents' answers based on certain categories, then calculating the percentage of occurrence of each category to see trends or tendencies of opinion. The interview instrument can be seen in Table 1.

Table 1. Interview Instrument Grid

Measured Aspects	Indicator
Vocational High School Students' Skill Needs	Technical competencies required in the industry
Suitability of Curriculum with the Industrial World	Relevance of learning to field practice
Advantages and Disadvantages of Existing Learning Models	The effectiveness of the learning models that have been applied
Expectations for the I-ProBL Model	I-ProBL's contribution to improving students' skills

To measure the feasibility of the model and the performance assessment instrument as well as input from the experts' point of view, a validation questionnaire is needed which can be seen in Table 2.

Table 2. Grid of Model Feasibility Validation Questionnaire Instrument

Measured Aspects	Indicator
Content Eligibility	Suitability of materials to industry needs
Clarity of Learning Models	Students' understanding of the I-ProBL model
Relevance to the World of Work	The model's ability to improve work readiness
Ease of Implementation	Teacher readiness in implementing the I-ProBL model

Furthermore, to test the effectiveness of the model, a practical performance assessment instrument is needed which will be applied at the end of the model treatment. The practical performance instrument can be seen in Table 3.

Table 3. Grid of Student Practical Test Instrument

Measured Aspects	Indicator
Concept Understanding	Ability to understand theory before practice
Engineering Skills	Students' ability to complete industrial projects
Problem Solving	Students' ability to solve problems in industry
Discipline and Cooperation	Student readiness to work in an industrial environment

Mean (Average) is used to determine the increase in student scores after the implementation of the I-ProBL model. Percentage is used to determine the distribution of student success rates in achieving certain competencies. The formula used in percentage analysis is:

$$P = \left(\frac{f}{N} \right) \times 100\%$$

P = Percentage, f = Frequency of answers in a certain category, N = Total number of respondents

Furthermore, the data from the validation questionnaire was analysed by calculating the average value (mean) to determine the feasibility level of the model, as well as the percentage of each score category to see the distribution of respondents' answers.

RESULTS & DISCUSSION

Needs Analysis

This stage is conducted to identify the gap between the skills of vocational school students and the needs of the industry. Interviews were conducted with 6 vocational school teachers and 3 industry practitioners. The results of the interviews can be seen in Table 4.

Table 4. Results of Teacher and Industry Interviews on Learning Needs

Aspects Asked	Teacher	Industry
Current job readiness of vocational school students	Students have a fairly good understanding of theory, but are still lacking in dealing with real problems in the world of work. Some students are also less disciplined and not yet accustomed to the rhythm of industrial work.	Vocational high school graduates still need a lot of additional training before they can work independently. They often lack confidence and lack understanding of industry work standards.
Compliance of curriculum with industry	The curriculum is quite relevant, but there is more theory than industry practice. Teachers feel the need for more industry-based projects.	The curriculum is still not well adapted to the needs of industry, especially in terms of work standards, safety and production efficiency.
Students' problem-	Students still have difficulty in	Students lack initiative in

Aspects Asked	Teacher	Industry
based learning skills	analyzing problems and finding solutions on their own. They tend to wait for teacher directions in completing assignments.	solving problems at work. They often just follow instructions without trying to find solutions themselves.
Students' practical skills	Students have fairly good basic practical skills in the school environment, but still lack experience in facing real challenges in the industry.	Students' practical skills still need to be improved, especially in handling real cases in industry and using more modern technology.

Interview results show that the work readiness of vocational high school students is still less than optimal, with practical and problem-solving skills that do not meet industry standards. The current curriculum still focuses more on theory than real practice, causing a gap between education and industry needs. Students tend to wait for direction in completing assignments, while industry expects graduates who are more independent and have initiative. To overcome this, I-ProBL integration is needed which involves real case studies, the involvement of industry mentors, and increased direct practice in the world of work. With this model, it is hoped that students will be better prepared to face industry challenges and have skills that are relevant to the needs of the job market.

Model Design

Based on the results of the needs analysis, the design of the I-ProBL model was developed with the main focus: (1) Industrial project-based learning to improve practical skills; (2) Collaboration with industry in developing learning and evaluation materials; and (3) Real problem solving from industry as the main teaching material. The stages of the I-ProBL model can be seen in table 4.

Table 5. Initial Design of I-ProBL Model Stages

Stages	Description
Identification of Industrial Problems	Students are given real problems from industry that are in line with their field of expertise.
Analysis and Discussion	Students analyze problems, discuss causes, and gather information with the guidance of teachers and industry mentors.
Solution Design	Students design technical and practical solutions based on the results of the analysis, such as prototyping or simulation.
Implementation and Testing	Students apply solutions in hands-on practice in school or industrial workshops, then test their effectiveness.
Evaluation and Feedback	Solutions are evaluated by teachers and industry, students receive feedback for skill improvement.
Presentation and Documentation	Students present their work and document the process as a work portfolio.

Model Development Stages

After the design, learning tools were developed, including industry-based learning modules and evaluation instruments. Model validation was conducted by 2 education and industry experts. The results of the validation stage can be seen in

Table 6.

Table 6. I-ProBL Model Validation Results by Experts

Assessment Aspects	Average Score	Category
Compliance with industry needs	4.6	Very good
Clarity of learning models	4.4	Good
Relevance to the world of work	4.7	Very good
Ease of implementation in schools	4.2	Good

The results of the I-ProBL model feasibility validation show that this model has a high level of suitability with industry needs (4.6, Very Good category) and is relevant to the world of work (4.7, Very Good category). This indicates that the I-ProBL model has succeeded in integrating industry skills into learning, ensuring that students acquire the competencies needed in the world of work. In terms of clarity of learning models, this model scored 4.4 (Good), indicating that the approach used is quite easy to understand by students and teachers. However, the aspect of ease of implementation in schools scored lower (4.2, Good category), indicating challenges in implementing this model, such as the availability of facilities, teacher readiness, and diverse industry support in each school.

Overall, the I-ProBL model was validated as an effective learning model in improving students' skills and strengthening the relationship between school and industry. However, for a more optimal implementation, additional support is needed in terms of teacher training, provision of learning resources, and closer collaboration between schools and businesses. After the model was validated by experts, it was revised to produce a model that is ready to be implemented in vocational schools. The model and its stages can be seen in Table 7.

Table 7. Stages of the Industry-based Problem-Based Learning Model (I-ProBL)

Stages	Stage Description	Perpetrator
Identification of Industry Needs and Problems	Analyze students' skill needs and gaps with the industrial world through interviews and collect real problems as teaching materials.	Teachers, Industry, Students
Design of Industry Based Learning Model	Developing industrial project-based learning scenarios, developing teaching tools, and designing collaboration mechanisms between schools and industry.	Teachers, Education Experts, Industry
Development of I-ProBL Learning Tools	Creating teaching modules, assessment rubrics, and model validation by education and industry experts to ensure their suitability to industry needs.	Teachers, Education Experts, Industry
Implementation of Models in Learning	Implementing industrial project-based learning, with students as problem solvers and direct industry involvement.	Teachers, Students, Industry
Model Evaluation and Refinement	Measure the effectiveness of the model through tests, questionnaires, and feedback from students, teachers,	Teachers, Students, Industry, Education Experts

Stages	Stage Description	Perpetrator
	and industry, then make improvements.	

The Industry-based Problem-Based Learning (I-ProBL) model was developed based on a needs analysis that showed a gap between the skills of vocational high school students and industry demands. Interviews with teachers and industry partners revealed that learning in schools is still not integrated enough with workplace practices, so students have difficulty applying their knowledge directly. Therefore, this model is designed with three main focuses: industrial project-based learning to improve practical skills, collaboration with industry in preparing learning materials and evaluations, and utilizing real problems from industry as the main teaching material. With this approach, it is hoped that students will be better prepared to face the challenges of the workplace, have relevant skills, and be able to think critically in solving industrial problems directly.

Implementation Stage (Model Implementation in Vocational Schools)

The I-ProBL model was piloted in three schools. A total of 90 students participated in this trial. The results of the implementation showed that the average score of students increased after following I-ProBL-based learning compared to the learning model that had been applied so far. Student test results before and after I-ProBL Implementation can be seen in Table 8.

Table 8. Student Test Results Before and After Implementation of I-ProBL

School	Pretest	Posttest	Increase (%)
A	68.5	82.3	20.1%
B	70.2	85.1	21.2%
C	66.8	80.5	20.5%

Based on the pretest and posttest data from the three SMKs that became the research subjects, there was a significant increase in students' average scores after the implementation of the Industry-based Problem-Based Learning (I-ProBL) model. School A experienced an increase of 20.1%, school B of 21.2%, and school C of 20.5%. These results indicate that the industrial project-based learning model is effective in improving students' conceptual understanding and practical skills. The largest increase occurred in school B which reached 21.2%, indicating that the implementation of the I-ProBL model in this school was well suited to the needs of the students and their learning environment. Overall, this data supports the conclusion that industry-based learning is able to bridge the gap between students' abilities and the demands of the world of work.

Evaluation Stage (Evaluation of Model Effectiveness)

Evaluation was conducted by analysing feedback from students and teachers through questionnaires. The questionnaire results showed that 85% of students felt that this model was more interesting than the previous model, and 90% of teachers stated that the I-ProBL model facilitated the teaching of industrial skills. The results of the student and teacher questionnaires on the I-ProBL Model can be seen in Table 9.

Table 9. Results of Student and Teacher Questionnaires on the I-ProBL Model

Assessment Aspects	Student Response (%)	Teacher Response (%)
Engagement in learning	85%	88%
Ease of understanding the material	80%	85%
Readiness to face the world of work	90%	92%
Ease of teaching for teachers	-	90%

Based on data from student and teacher responses to the implementation of the Industry-based Problem-Based Learning (I-ProBL) model, it can be seen that this model has received positive responses. Student involvement in learning reached 85%, in line with teacher responses of 88%, indicating that this model is able to increase active student participation. In terms of ease of understanding the material, students gave a response of 80%, while teachers gave 85%, indicating that the industrial project-based approach facilitates the learning process.

The highest aspect is readiness to face the world of work, with 90% student responses and 92% teacher responses, indicating that this model is effective in equipping students with relevant skills. In addition, the ease of teachers in teaching reached 90%, indicating that this model also supports teaching effectiveness. Overall, these data confirm that the I-ProBL model not only improves students' understanding, but also strengthens their readiness to face the challenges of the industrial world.

Results and Discussion contains a detailed description of all research results along with their analysis. Research results can be supplemented with tables, graphs, images and/or charts. Results and discussion can be separated or explained directly. If the results of the discussion are presented directly, include a sub-discussion so that readers can easily digest the information presented. The discussion contains the meaning of the results and comparisons with theories and/or similar research results.

Discussion

The Industry-based Problem-Based Learning (I-ProBL) model in vocational education aims to reduce the skills gap between students and the industrial world. By integrating problem-based learning taken directly from the world of work, students can gain a deeper understanding of industrial practices. The problem-based approach model can improve students' critical thinking and problem-solving skills that are needed in the world of work (Alongkrontuksin et al., 2024; Boelt et al., 2022; Poojar et al., 2017).

The first step in I-ProBL is the identification of an industrial problem, where students are given a real challenge related to their area of expertise, such as machine repair or production system optimisation. At this stage, teachers and industry partners work together to select appropriate problems, so that students can practice solving challenges that are truly relevant to the world of work. This model is particularly well-suited for vocational sectors such as manufacturing, automotive, and engineering, where hands-on problem-solving and real-world application are essential. Problem-based models help students to be more independent in finding

solutions and improve their analytical skills (Nicholus et al., 2023; Salvador et al., 2023).

After identifying the problem, students proceed to the analysis and discussion stage, where they analyse the causes and impacts of the given problem. In this process, they gather information, discuss with group members, and receive guidance from teachers and industry mentors. Problem-based discussions can improve critical thinking skills and encourage collaboration, which are important skills in the industrialised world (Khasawneh, 2024; Kovalchuk et al., 2022; Shahzad et al., 2017).

The next stage is solution design, where students design various alternative solutions based on the analysis that has been done. They may create simulations, prototypes, or develop other technical models that are appropriate to the challenge at hand. This stage helps students to connect theory with practice and enhance their innovation in solving real-world problems (Khasawneh, 2024; Kovalchuk et al., 2022; Shahzad et al., 2017).

Next, the students apply their solutions through implementation and testing in real environments, both in the school workshop and partner industries. At this stage, they can test the effectiveness of the designed solutions and gain hands-on experience in the industrial world. Project-based learning supported by direct involvement from industry can significantly improve students' technical skills and professionalism (Ahmed et al., 2024; Nopriana et al., 2023; Qing, 2022; Wang et al., 2023).

After the implementation, an evaluation and feedback is conducted, where the students' work is assessed by the teacher and industry supervisor. This evaluation aims to measure the effectiveness of learning and provide suggestions for improvement for students. Model validation data shows that I-ProBL has high relevance to industry needs and can improve students' work readiness. The industry-based I-ProBL model is able to improve students' practical skills and their readiness to enter the world of work (Kolmos et al., 2020; Zhang et al., 2022).

However, there are several challenges in implementing this model, such as teachers' readiness to implement the new model, limited facilities, and variations in the level of industry involvement in various schools (Erwin et al., 2023; Firsta et al., 2024). These challenges may affect the consistency and overall effectiveness of the model across different institutions. For example, insufficient teacher training can hinder the facilitation of problem-based learning, while inadequate infrastructure limits students' opportunities to engage in authentic industrial simulations. Additionally, unequal industry participation may result in varying learning experiences among schools (Al-Zahrani, 2024; Deroncele-Acosta & Ellis, 2024). The success of the problem-based learning model is highly dependent on institutional readiness and support from various parties. Therefore, training for teachers and improvement of facilities are needed to support the effectiveness of industry-based learning (Du et al., 2022; Nicholus et al., 2023).

In addition, several cases have been reported where students have difficulty adapting to the I-ProBL approach. Some students have difficulty with the open-ended nature of problem-solving tasks, especially those accustomed to more structured and directed learning methods. In some contexts, students have also reported discomfort when industry problems are too complex or unfamiliar,

resulting in frustration and decreased motivation. Group dynamics can also be a barrier when collaboration is not well facilitated, resulting in uneven participation among team members. These cases highlight the importance of incremental support, clear guidance, and the role of the teacher as a facilitator to help students transition to a more independent learning role (Almulla, 2020; Gholam, 2019; Yu & Zin, 2023).

Overall, the results of this study indicate that I-ProBL is an effective learning model in improving students' skills and is relevant to the needs of the workplace. For wider implementation, a strategy is needed to strengthen cooperation between schools and industry and provide adequate infrastructure. Further research is also needed to explore ways to improve the effectiveness of this model in various vocational education contexts.

CONCLUSION

Implications: The findings suggest that the Industry-Based Problem-Based Learning (I-ProBL) model can be an effective learning strategy to bridge the gap between SMK students' competencies and industry needs. The implementation of this model can encourage the transformation of curriculum and learning approaches in SMK to be more contextualised and applicable. In addition, this model encourages the active involvement of industry in education, thereby strengthening collaboration between schools and the work sector.

Limitations: However, this study still faces some limitations. Teachers' low readiness to implement the industrial project-based model, limited supporting facilities in schools, and uneven involvement of industry partners are significant challenges. In addition, the application of this model is still limited to three vocational schools, so the generalisation of the research results is still limited.

Further Research: Future research can focus on developing a sustainable training system for teachers to be better prepared to implement I-ProBL, as well as exploring strategies to expand industrial partnership networks, especially for SMKs in remote areas. Further studies are also recommended to test the effectiveness of this model in other fields of expertise and on a wider scale to obtain more representative results and enrich the development of industry-based vocational learning models.

REFERENCES

- Abdurrahman, I. S., Mahmudah, F. N., Santosa, A. B., Paryono, P., Saryadi, S., & Cahyono, S. M. (2022). Collaborative online learning: implementation of vocational alignment in accordance with industry's needs. *Jurnal Pendidikan Teknologi Dan Kejuruan*, 29(1), 23–33. <https://doi.org/10.21831/jptk.v29i1.53082>
- Afriani, C., Gimin, G., & Hendripides, H. (2023). Analysis of Teacher Readiness in Implementing the Independent Learning Curriculum. *JETISH: Journal of Education Technology Information Social Sciences and Health*, 2(2), 1670–1677. <https://doi.org/10.57235/jetish.v2i2.780>

- Ahmed, S., Grollo, L., & Czech, D. (2024). The Journal of Teaching and Learning for Graduate Employability Industry Perspectives on Project-Based Learning as a Form of Work- Integrated Learning in Science. *The Journal of Teaching and Learning for Graduate Employability* ISSN:, 15(1), 225–248. <https://doi.org/https://doi.org/10.21153/jtlge2024vol15no1art1879>
- Al-Zahrani, A. M. (2024). Unveiling the shadows: Beyond the hype of AI in education. *Heliyon*, 10(9), e30696. <https://doi.org/10.1016/j.heliyon.2024.e30696>
- Alferez-Pastor, M., Collado-Soler, R., Lérída-Ayala, V., Manzano-León, A., Aguilar-Parra, J. M., & Trigueros, R. (2023). Training Digital Competencies in Future Primary School Teachers: A Systematic Review. *Education Sciences*, 13(5). <https://doi.org/10.3390/educsci13050461>
- Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. *SAGE Open*, 10(3). <https://doi.org/10.1177/2158244020938702>
- Alongkrontuksin, C., Korakotjintanakarn, P., & Saehaew, T. (2024). Industrial based learning for improving problem solving skill for technical workforce labour. *Revista de Gestão Social e Ambiental*, 18(5), 1–18. <https://doi.org/https://doi.org/10.24857/rgsa.v18n5-128>
- Amante, S., & Fernandes, R. (2023). Aligning HE Pedagogical Innovation with VET, Industry, and Research Partnerships: Insights on the Demola Portugal Initiative. *Education Sciences*, 13(1). <https://doi.org/10.3390/educsci13010093>
- Ashraf, A. R., Thongpapanl, N., Menguc, B., & Northey, G. (2017). The Role of M-commerce readiness in emerging & developed markets. *Journal of International Marketing*, 25(2), 25–51. <https://doi.org/10.1509/jim.16.0033>
- Aslam, S., Alghamdi, A. A., Abid, N., & Kumar, T. (2023). Challenges in Implementing STEM Education: Insights from Novice STEM Teachers in Developing Countries. *Sustainability (Switzerland)*, 15(19). <https://doi.org/10.3390/su151914455>
- Boelt, A. M., Kolmos, A., & Holgaard, J. E. (2022). Literature review of students' perceptions of generic competence development in problem-based learning in engineering education. *European Journal of Engineering Education*, 47(6), 1399–1420. <https://doi.org/10.1080/03043797.2022.2074819>
- Börner, K., Scrivner, O., Gallant, M., Ma, S., Liu, X., Chewning, K., Wu, L., & Evans, J. A. (2018). Skill discrepancies between research, education, and jobs reveal the critical need to supply soft skills for the data economy. *Proceedings of the National Academy of Sciences of the United States of America*, 115(50), 12630–12637. <https://doi.org/10.1073/pnas.1804247115>
- Çınar, Z. M., Zeeshan, Q., & Korhan, O. (2021). A framework for industry 4.0 readiness and maturity of smart manufacturing enterprises: A case study. *Sustainability (Switzerland)*, 13(12). <https://doi.org/10.3390/su13126659>
- Deroncele-Acosta, A., & Ellis, A. (2024). Overcoming Challenges and Promoting Positive Education in Inclusive Schools: A Multi-Country Study. *Education Sciences*, 14(11). <https://doi.org/10.3390/educsci14111169>
- Du, X., Guerra, A., Nørgaard, B., Chaaban, Y., Lundberg, A., & Lyngdorf, N. E. R. (2022). University Teachers' Change Readiness to Implement Education for Sustainable Development through Participation in a PBL-Based PD Program. *Sustainability (Switzerland)*, 14(19). <https://doi.org/10.3390/su141912079>
- Erwin, G., Mige, S., Setyosari, P., Ulfa, S., & Praherdiono, H. (2023). The Effect of Blended PBL Assisted with Advance Organizer and Thinking Style on Understanding and Application of Digital Electronics Concepts. *Jurnal Teknologi Pendidikan*, 25(December), 641–653.
- Finnveden, G., & Schneider, A. (2023). Sustainable Development in Higher Education—

- What Sustainability Skills Do Industry Need? *Sustainability (Switzerland)*, 15(5), 1–7. <https://doi.org/10.3390/su15054044>
- Firsta, M., Sara, K., Irfan, D., & Maksum, H. (2024). Development of Moodle-Based E-Learning Media in Workshop and Entrepreneurship Learning. *Jurnal Teknologi Pendidikan*, 26(August), 689–699.
- Gallagher, A. G., Hart, M., Cleary, D., Hamilton, C., McGlinchey, K., Kiely, P., & Bunting, B. P. (2020). Proficiency based progression simulation training significantly reduces utility strikes; A prospective, randomized and blinded study. *PLoS ONE*, 15(5), 1–14. <https://doi.org/10.1371/journal.pone.0231979>
- Gerschewski, S., Scott-Kennel, J., & Rose, E. L. (2020). Ready to export? The role of export readiness for superior export performance of small and medium-sized enterprises. *World Economy*, 43(5), 1253–1276. <https://doi.org/10.1111/twec.12928>
- Gholam, A. (2019). Inquiry-Based Learning: Student Teachers' Challenges and Perceptions. *Journal of Inquiry & Action in Education*, 10(2), 112–133.
- Govindan, K., & Arampatzis, G. (2023). A framework to measure readiness and barriers for the implementation of Industry 4.0: A case approach. *Electronic Commerce Research and Applications*, 59(July 2021), 101249. <https://doi.org/10.1016/j.elerap.2023.101249>
- Groeneveld, W., Vennekens, J., & Aerts, K. (2022). Identifying Non-Technical Skill Gaps in Software Engineering Education: What Experts Expect But Students Don't Learn. *ACM Transactions on Computing Education*, 22(1), 1–21. <https://doi.org/10.1145/3464431>
- Groulx, P., Maisonneuve, F., Harvey, J. F., & Johnson, K. J. (2024). The ripple effect of strain in times of change: how manager emotional exhaustion affects team psychological safety and readiness to change. *Frontiers in Psychology*, 15(March), 1–10. <https://doi.org/10.3389/fpsyg.2024.1298104>
- Hariani, L. S., Mohamad, M. bin, & Sulistyono, S. (2023). How can HOTS for Vocational High School Students be Enhanced through the Problem-Based Learning model? *AL-ISHLAH: Jurnal Pendidikan*, 15(4), 5816–5824. <https://doi.org/10.35445/alishlah.v15i4.4605>
- Hidayatulloh, M. K. Y., & Ashoumi, H. (2022). The perspective of work readiness in vocational school students with 21st century communication and collaboration skills. *Cypriot Journal of Educational Sciences*, 17(7), 2199–2206. <https://doi.org/10.18844/cjes.v17i7.7588>
- Hoidn, S., & Šťastný, V. (2023). Labour Market Success of Initial Vocational Education and Training Graduates: A Comparative Study of Three Education Systems in Central Europe. *Journal of Vocational Education and Training*, 75(4), 629–653. <https://doi.org/10.1080/13636820.2021.1931946>
- Jackson, D. (2018). Developing graduate career readiness in Australia: Shifting from extra-curricular internships to work-integrated learning. *International Journal of Work-Integrated Learning*, 19(1), 23–35.
- Khasawneh, M. A. S. (2024). The Challenges Facing Vocational Education Online from the Teachers' Perspectives. *Journal of Curriculum and Teaching*, 13(2), 180–196. <https://doi.org/10.5430/jct.v13n2p180>
- Kolmos, A., Holgaard, J. E., & Clausen, N. R. (2020). Progression of student self-assessed learning outcomes in systemic PBL. *European Journal of Engineering Education*, 1–23. <https://doi.org/10.1080/03043797.2020.1789070>
- Kovalchuk, V., Maslich, S., Tkachenko, N., Shevchuk, S., & Shchypyska, T. (2022). Vocational Education in the Context of Modern Problems and Challenges. *Journal of Curriculum and Teaching*, 11(8), 329–338. <https://doi.org/10.5430/jct.v11n8p329>
- Liu, S. (2022). Fit of Professional Setting and Regional Industrial Structure of Financial

- Colleges in the Greater Bay Area from Industry-Education Integration. *Wireless Communications and Mobile Computing*, 2022. <https://doi.org/10.1155/2022/2058438>
- Lv, Y., Wu, M., & Shouse, R. C. (2022). Impact of organizational culture, occupational commitment and industry-academy cooperation on vocational education in China: Cross-sectional Hierarchical Linear Modeling analysis. *PLoS ONE*, 17(2 February), 1–18. <https://doi.org/10.1371/journal.pone.0264345>
- Mada Aditia Wardhana, Ida Aju Brahmastari, & Ida Aju Brahma Ratih. (2023). Workplace learning in an effort to get recognition of Indonesian qualifications framework for career enhancement and employee competitiveness. *World Journal of Advanced Research and Reviews*, 18(3), 494–504. <https://doi.org/10.30574/wjarr.2023.18.3.1094>
- Mahmudah, F. N., Baswedan, A. A. G. R., Usman, H., Mardapi, D., & Putra, E. C. S. (2022). the Importance of Partnership Management To Improve School-To-Work Transition Readiness Among Vocational High School Graduates. *Obrazovanie i Nauka*, 24(5), 64–89. <https://doi.org/10.17853/1994-5639-2022-5-64-89>
- Michaelis, C., & Findeisen, S. (2022). Influence of Person-Vocation Fit on Satisfaction and Persistence in Vocational Training Programs. *Frontiers in Psychology*, 13(February), 1–16. <https://doi.org/10.3389/fpsyg.2022.834543>
- Montt-Blanchard, D., Najmi, S., & Spinillo, C. G. (2023). Considerations for Community Engagement in Design Education. *She Ji*, 9(2), 234–263. <https://doi.org/10.1016/j.sheji.2023.05.004>
- Naranjo, J. E., Sanchez, D. G., Robalino-Lopez, A., Robalino-Lopez, P., Alarcon-Ortiz, A., & Garcia, M. V. (2020). A scoping review on virtual reality-based industrial training. *Applied Sciences (Switzerland)*, 10(22), 1–31. <https://doi.org/10.3390/app10228224>
- Nicholus, G., Muwonge, C. M., & Joseph, N. (2023). The Role of Problem-Based Learning Approach in Teaching and Learning Physics: A Systematic Literature Review. *F1000Research*, 12, 1–24. <https://doi.org/10.12688/f1000research.136339.2>
- Nopriana, T., Herman, T., & Martadiputra, B. A. P. (2023). Digital Didactical Design: The Role of Learning Obstacles in Designing Combinatorics Digital Module for Vocational Students. *International Journal of Interactive Mobile Technologies*, 17(2), 4–23. <https://doi.org/10.3991/ijim.v17i02.34293>
- Orieno, O. H., Udeh, C. A., Oriekhoe, O. I., Odonkor, B., & Ndubuisi, N. L. (2024). Innovative Management Strategies in Contemporary Organizations: a Review: Analyzing the Evolution and Impact of Modern Management Practices, With an Emphasis on Leadership, Organizational Culture, and Change Management. *International Journal of Management & Entrepreneurship Research*, 6(1), 167–190. <https://doi.org/10.51594/ijmer.v6i.727>
- Poojar, B., Ommurugan, B., Adiga, S., Thomas, H., Sori, R. K., Poojar, B., Hodlur, N., Tilak, A., Korde, R., Gandigawad, P., In, M., Sleep, R., Albino, D., Rats, W., Article, O., Schedule, P., Injury, C. C., Sori, R. K., Poojar, B., ... Gandigawad, P. (2017). Methodology Used in the Study. *Asian Journal of Pharmaceutical and Clinical Research*, 7(10), 1–5. <https://doi.org/10.4103/jpbs.JPBS>
- Pop, B. O., Popescu, C., & Gabor, M. R. (2023). Process and Product Change Management as a Predictor and Innovative Solution for Company Performance: A Case Study on the Optimization Process in the Automotive Industry. *Applied System Innovation*, 6(5). <https://doi.org/10.3390/asi6050075>
- Qing, L. (2022). Research on Intelligent Function Design of Vocational Education System under Mobile Learning Mode. *Journal of Mathematics*, 2022. <https://doi.org/10.1155/2022/9684363>

- Rahayu, S., Meirawan, D., Muktiarni, M., Ghinaya, Z., & Sabitri, Z. (2024). Analyzing Transferable Skills of Vocational Students To Align With Industry Demands. *Jurnal PenSil*, 13(1), 34–46. <https://doi.org/10.21009/jpensil.v13i1.39803>
- Riska Dwi Anggraini, Tjipto Prastowo, & Elok Sudibyo. (2022). Analysis of Problem Solving Skills in the Vocational High School Using Direct Current Electricity as A Case Study. *IJORER : International Journal of Recent Educational Research*, 3(3), 301–311. <https://doi.org/10.46245/ijorer.v3i3.219>
- Rodzalan, S. A., Mohd Noor, N. N., Abdullah, N. H., & Mohamed Saat, M. (2022). TVET Skills Gap Analysis in Electrical and Electronic Industry: Perspectives from Academicians and Industry Players. *Journal of Technical Education and Training*, 14(1). <https://doi.org/10.30880/jtet.2022.14.01.014>
- Saengrith, W., Viriyavejakul, C., & Pimdee, P. (2022). Problem-Based Blended Training via Chatbot to Enhance the Problem-Solving Skill in the Workplace. *Emerging Science Journal*, 6(Special Issue), 1–12. <https://doi.org/10.28991/ESJ-2022-SIED-01>
- Sakdapat, N. (2024). Approaches for sustainable professional skill development for vocational education students in Thailand. *F1000Research*, 13, 1–16. <https://doi.org/10.12688/f1000research.146802.1>
- Salvador, R., Barros, M. V., Barreto, B., Pontes, J., Yoshino, R. T., Piekarski, C. M., & de Francisco, A. C. (2023). Challenges and opportunities for problem-based learning in higher education: Lessons from a cross-program Industry 4.0 case. *Industry and Higher Education*, 37(1), 3–21. <https://doi.org/10.1177/09504222221100343>
- Schwede, J., Heisler, D., & Harteis, C. (2025). Integrating Practice-Based Learning into Formal Education: Stakeholder Perspectives on the Challenges of Learning Location Cooperation (LLC) in Germany’s Dual VET System. *Social Sciences*, 14(3). <https://doi.org/10.3390/socsci14030117>
- Shahzad, M. W., Jamil, M. A., Nazirul, M., Sarker, I., & Wu, M. (2017). Assessment of multiple subjects’ synergetic governance in vocational education. *Frontiers in Psychology*, 13(3), 01–11.
- Sharma, K., Nigam, N., Jha, J. K., & Xu, X. (2024). Role of Readiness to Change in the Relationship Between Workforce Agility and Digital Transformation: A Two-Timeframe Study. *Journal of Global Information Management*, 32(1). <https://doi.org/10.4018/JGIM.345241>
- Silva, R., Martins, F., Cravino, J., Martins, P., Costa, C., & Lopes, J. B. (2023). Using Educational Robotics in Pre-Service Teacher Training: Orchestration between an Exploration Guide and Teacher Role. *Education Sciences*, 13(2). <https://doi.org/10.3390/educsci13020210>
- Simon, P. D., & Zeng, L. M. (2024). Behind the Scenes of Adaptive Learning: A Scoping Review of Teachers’ Perspectives on the Use of Adaptive Learning Technologies. *Education Sciences*, 14(12), 1–18. <https://doi.org/10.3390/educsci14121413>
- Song, X., & Xu, D. (2024). More Graduates, Fewer Skills? Vocational Education Expansion and Skilled Labour Shortages in China. *China Quarterly*, 1–16. <https://doi.org/10.1017/S0305741023001856>
- Van Nguyen, T., Cao, C. D., & Nguyen, H. T. (2022). Assessment of Perception Factors Influencing Collaboration Between Vocational Schools and Businesses in Practical Training. *Humanities and Social Sciences Letters*, 10(3), 290–300. <https://doi.org/10.18488/73.v10i3.3055>
- Wang, X., Lee, C. F., Li, Y., & Zhu, X. (2023). Digital Transformation of Education: Design of a “Project-Based Teaching” Service Platform to Promote the Integration of Production and Education. *Sustainability (Switzerland)*, 15(16). <https://doi.org/10.3390/su151612658>

- Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, 8. <https://doi.org/10.3389/feduc.2023.1139987>
- Zhang, L., Huang, Z., Wang, T., Zhao, N., Cheng, H., & Chen, W. (2022). Lean combustion and emission performance of a gasoline direct injection engine with active pre-chamber. *Advances in Mechanical Engineering*, 14(7), 1–13. <https://doi.org/10.1177/16878132221113453>