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ORIGINAL

Embedding Digital Literacy into Problem-Based Learning to Foster Creativity in Diagnosing EFI Systems: A Vocational Education Innovation

Integración de la Alfabetización Digital en el Aprendizaje Basado en Problemas para Fomentar la Creatividad en el Diagnóstico de Sistemas EFI: Una Innovación en la Educación Vocacional

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ABSTRACT

Introduction: vocational students often struggle to diagnose EFI systems due to the abstract nature of the concepts and limited digital skills. Conventional teaching methods fall short in fostering creativity for solving complex technical problems. This study aimed to develop and evaluate a Problem-Based Learning model integrated with Digital Literacy (PBL-DL) to enhance students' creativity in diagnosing EFI systems.
Method: using an adapted Borg and Gall development model, the study involved 176 participants, including teachers, students, and media/material experts. The research proceeded through four stages: preliminary study, design and development, user response testing, and effectiveness testing. Data collection instruments included questionnaires, expert validation checklists, and creativity observation sheets. Analyses used descriptive statistics, paired *t*-tests, and independent *t*-tests.
Results: the PBL-DL model significantly improved students' creativity in diagnosing EFI systems. Indicators such as fluency, originality, and elaboration showed statistically significant increases. The integration of digital tools also enhanced students' access to and engagement with learning materials. The model shows potential for broader application in other complex vocational learning contexts.
Conclusions: integrating digital literacy into problem-based learning strengthens students' creative problem-solving and classroom engagement. The PBL-DL framework contributes to more effective vocational education while supporting the development of essential 21st-century skills.

Keywords: Digital Literacy; Vocational Education; Creativity; EFI Diagnosis; Problem-Based Learning.

RESUMEN

Introducción: los estudiantes de formación profesional suelen enfrentar dificultades al diagnosticar sistemas EFI debido a la naturaleza abstracta de los conceptos y a sus limitadas habilidades digitales. Los métodos de enseñanza tradicionales no logran fomentar la creatividad necesaria para resolver problemas técnicos

complejos. Este estudio tuvo como objetivo desarrollar y evaluar un modelo de Aprendizaje Basado en Problemas integrado con Alfabetización Digital (ABP-AD) para mejorar la creatividad de los estudiantes en el diagnóstico de sistemas EFI.
Método: utilizando un modelo de desarrollo adaptado de Borg y Gall, el estudio involucró a 176 participantes, incluidos docentes, estudiantes y expertos en medios y materiales educativos. La investigación se llevó a cabo en cuatro etapas: estudio preliminar, diseño y desarrollo, prueba de respuesta del usuario y evaluación de la efectividad. Se utilizaron cuestionarios, listas de validación de expertos y hojas de observación de la creatividad. El análisis se realizó mediante estadísticas descriptivas y pruebas *t* pareadas e independientes.
Resultados: el modelo ABP-AD mejoró significativamente la creatividad de los estudiantes para diagnosticar sistemas EFI. Indicadores como fluidez, originalidad y elaboración mostraron aumentos estadísticamente significativos. La integración de herramientas digitales también mejoró el acceso y la participación de los estudiantes en los materiales de aprendizaje. El modelo tiene potencial para ser aplicado en otros contextos de formación técnica compleja.
Conclusiones: La integración de la alfabetización digital en el aprendizaje basado en problemas fortalece la capacidad creativa para la resolución de problemas y mejora la participación en el aula. El modelo ABP-AD representa un avance en la educación profesional y promueve habilidades clave del siglo XXI.

Palabras clave: Alfabetización Digital; Educación Vocacional; Creatividad; Diagnóstico EFI; Aprendizaje basado en Problemas.

INTRODUCTION

Automotive Engineering (AE) is an area of expertise in vocational education. Various researchers see AE as a field with highly complex learning outcomes.[1,2] The general competencies taught cover the cognitive, affective, and psychomotor domains.[3] Meanwhile, the skills that must be mastered are identification, understanding the construction and workings of the system, care, maintenance, and troubleshooting the system.[4] This complexity is often considered by educational practitioners in the field of AE, especially teachers, in managing learning to achieve complex skills.[5] These concerns are also experienced by students, as noted by Nasrudi et al.[6], who found high learning difficulties in several units of competency, as evidenced by low learning outcomes. One of the most concerned units of competency is the diagnosis of the electronic fuel injection (EFI) system in motorcycle vehicles.[6,7] The EFI system is a fuel spraying system whose working process is electronically controlled, enabling fuel spraying efficiency tailored to the engine's needs. The complexity of the electronic construction of this system, which is abstract, makes it difficult to achieve learning outcomes when diagnosing the damage that occurs.[8]

Diagnosis in these systems is synonymous with the process of problem-solving with in-depth discovery and identification methods.[9] Therefore, to overcome the problem of low diagnostic results, teachers adopt a problem-based learning (PBL) model. PBL is a problem-centred learning model to be solved by students through systematic steps with a scientific approach.[10,11,12] In general, problem-based learning can be approached through five key stages: defining, organizing, hypothesizing, testing, and evaluating.[13,14,15] In the context of the EFI system, PBL can be illustrated by starting with initial testing of system conditions, organizing based on initial system data, proposing temporary conjectures from the initial test results, making system measurements, and finally evaluating them.[16] However, studies have yet to be specific in addressing the problem of students' difficulties in diagnosing damage to the EFI system.[6,17] The implementation of PBL in vocational education in certain fields can be a trap for teachers in terms of time efficiency and effectiveness in achieving learning objectives. As a result, students are confined to procedural problem-solving activities whose answers are uncertain.[18]

Tan said that the application of PBL should be oriented to stimulate students' learning creativity.[19,20] Learning creativity is a creative thinking process skill that enables students to produce new ideas successfully and continue to develop them through a learning process that integrates effective learning methods. Creativity is a crucial aspect that can contribute to increased efficiency and effectiveness in problem-solving.[21] Furthermore, emphasized that creativity offers an alternative approach to preventing problems from escalating.[22] In addition, the characteristics of the EFI system, whose electrical pathways are abstract, require creativity to facilitate a quick understanding of the system.[6] The speed of the thinking process in identifying these problems is also a qualification prioritized by the world of work.[23] Therefore, PBL managers must innovate in implementing it so that student learning creativity can be optimally pursued to support the learning process of diagnosing the EFI system effectively and efficiently.

Digitalization in learning is a leading option that can be integrated to enhance students' learning creativity in diagnosing EFI systems.[24,25] Digital media has provided a vast space for learners to explore knowledge and build their skills.[26,27,28] The easy-access process, which can be completed at any time and from anywhere, provides high flexibility to students, allowing for optimal learning efficiency.[29,30] However, several studies warn that integrating digital technology requires strong digital literacy (DL). DL is a fundamental aspect that underpins skills such as accessibility, accuracy, relevance, and ethical use, as well as the justification of digital resources used as a support tool for PBL problem-solving.[31,32] DL can increase understanding in problem-solving and speed up the work process effectively.[33] Therefore, DL is very important to be integrated into PBL in order to increase students' learning creativity in diagnosing damage to the EFI system. This research specifically aims to design a problem-based learning (PBL) model with a focus on integrating digital literacy (DL) in its application. More specifically, aspects of digital literacy are integrated into the structure of PBL, allowing learning practitioners, including students, to understand the structure comprehensively and develop an attitude to sort out digital learning resources effectively.

METHOD

Research Design

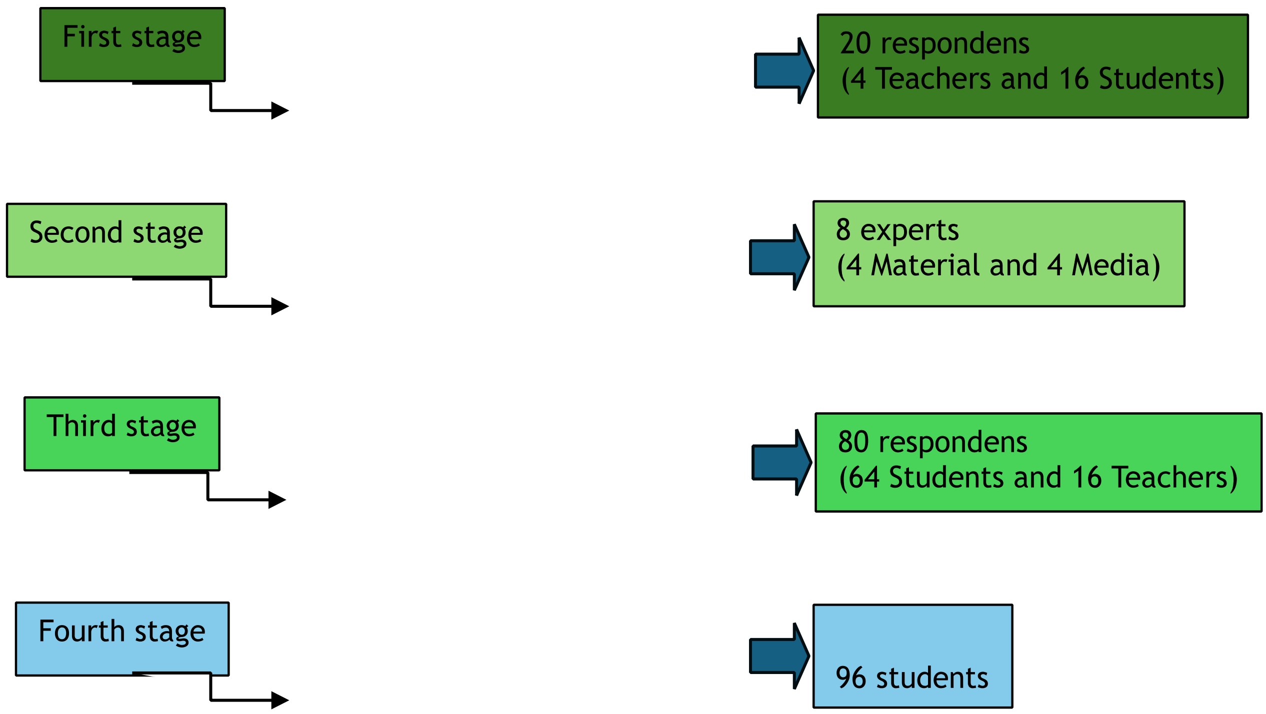

Figure 1. Stages of Educational Development Research in Designing and Creating the Product

This study is an educational development research adapted from Plomp.[34] The research followed several stages, which included a preliminary study, product design and development, user response testing, and effectiveness testing through a quasi-experimental design. The study aimed to produce an educational product tailored to user needs. The entire design process involved key stakeholders, including vocational teachers, media and content experts, as well as vocational students. These stages were believed to contribute to the creation of an effective product capable of enhancing students' competencies in accordance with industry demands. Educational development research is considered capable of producing valuable products aligned with the needs of both students and teachers due to their transparent involvement throughout the process. The stages of this development research are illustrated in figure 1.

This study involved 204 respondents, comprising 20 vocational teachers (9,8 %), 176 vocational students (86,3 %), and eight media and content experts (3,9 %). The selection of the number and composition of respondents was based on the need to include various stakeholders relevant to the context of developing a learning product for two-wheeled vehicle EFI systems. To ensure a representative and comprehensive data distribution, respondents were selected from both public and private schools, taking into account the differing characteristics, resources, and instructional challenges of these two types of institutions. The detailed characteristics of the respondents are presented in table 1 below.

Table 1. Distribution of Respondents by Research Stage (N=204)			
Stages	**Characteristics**	**Number (n)**	**Percentage (%)**
Preliminary study	Vocational teachers[a)]	2	0,98
	Vocational teachers[b)]	2	0,98
	Vocational students[a)]	8	3,92
	Vocational students[b)]	8	3,92
Development	Material experts	4	1,96
	Media experts	4	1,96
Evaluation (user response testing)	Vocational teachers[a)]	6	2,94
	Vocational teachers[b)]	10	4,90
	Vocational students[a)]	23	11,27
	Vocational students[b)]	41	20,10
Implementation (Effectiveness testing)	Vocational students[a)]	23	11,27
	Vocational students[a)] (Control class)	23	11,27
	Vocational students[b)]	25	12,25
	Vocational students[b)] (Control class)	25	12,25
Notes: a) State Vocational Schools and b) Private Vocational Schools			

The sampling technique employed was purposive sampling for vocational teachers and subject-matter experts, and proportional stratified random sampling for vocational students. Teachers were selected based on specific criteria, namely, their role as instructors of EFI fuel system courses and a minimum of three years of teaching experience. Students were proportionally selected from Grades XI and XII of the Light Vehicle Engineering and Motorcycle Engineering programs, and had completed coursework related to the EFI system.

Table 2. Validation Criteria for Material and Media Experts			
Expert Type	**Respondent Code**	**Expertise**	**Description**
Expert of Material (EMa)	EMa1	Professor – Automotive Engineering	Professor with 42 years of teaching experience in automotive engineering. Actively involved in research and development of instructional models and serves as an advisor to the national automotive professional association.
	EMa2	Associate Professor - Automotive Engineering	30 years of experience in teaching automotive engineering. Involved in developing instructional models, certified BNSP assessor, automotive instructor, and collaborator with PT Astra Daihatsu Indonesia.
	EMa3	Associate Professor - Automotive Engineering	29 years of experience in automotive instruction. Participated in instructional development, certified BNSP assessor, and partnered with PT Nissan Indonesia.
	EMa4	Associate Professor - Automotive Engineering	32 years of experience in teaching and model development. Acts as BNSP assessor and collaborates with PT Nissan Indonesia in vocational education.
Expert of Media (EMe)	EMe1	Professor – Learning Media	36 years of teaching in learning media. Focuses on digital media development and serves as a consultant in technology-based instructional design.
	EMe2	Professor – Learning Media	38 years of experience in instructional media, BNSP assessor, and expert consultant in VR/AR-based media development.
	EMe3	Associate Professor - Learning Media	30 years of teaching. Specialized in AI-integrated learning media, certified BNSP assessor in Indonesia.
	EMe4	Associate Professor - Learning Media	37 years of experience in VR/AR-based instructional media development, certified BNSP assessor in Indonesia.

Meanwhile, the eight experts involved in product validation and evaluation comprised four subject-matter experts and four media experts. These experts were selectively recruited through purposive sampling, based on their academic qualifications in the field of automotive engineering education (for subject-matter experts) and instructional technology or media (for media experts) as presented in table 2. Additionally, they possessed extensive professional experience, ranging from 29 to 42 years, in their respective fields, including university lecturing, instructional media development, vocational education consulting, and BNSP certification as assessors. All experts had also been actively engaged in the development of learning models or technology-based digital media, and had track records of collaboration with automotive industries such as PT Astra Daihatsu and PT Nissan Indonesia, as well as in the development of technology-integrated media for vocational education.

This approach was adopted to ensure the validity of the developed product, optimize user responses, and secure credible assessments from field experts. All procedures were designed by systematic principles of educational product development, ensuring academic accountability and alignment with the stages of educational design research.

Collection Data and Instruments

The preliminary study stage was conducted from November to December 2024. Data were collected to identify curriculum needs, required competencies, teaching materials, and learning challenges related to the two-wheeled vehicle EFI system. A total of 20 respondents participated in this stage, consisting of 4 vocational teachers and 16 students. Data collection techniques included surveys, limited interviews, and focus group discussions (FGDs). The instruments used were questionnaires comprising 16 items, covering aspects such as the use of media and instructional models, student learning outcomes, and support for instructional development.[35]

The design and development stage took place from January to March 2025. During this phase, the researchers designed a guidebook for a Problem-Based Learning (PBL) model integrated with digital literacy, based on the analysis from the preliminary study. The draft product was then validated by eight experts, comprising four subject-matter experts and four media experts. Validation was conducted using a structured questionnaire. The subject-matter experts assessed content relevance, instructional syntax, language, and formatting across 21 items.[17] Meanwhile, media experts evaluated the design, visualization, consistency, contextual alignment, and user-friendliness across 16 items.[12]

Subsequently, the evaluation stage (user response testing) was conducted in March 2025, involving limited trials to assess user perceptions of the developed product. A total of 80 vocational students participated in the event. Data were gathered using a perception questionnaire consisting of 12 items, focusing on design and visualization, consistency, ease of use, and language appropriateness.[12]

The final stage, implementation (effectiveness testing), was carried out in April 2025 using a quasi-experimental design with a pretest-posttest control group format. The experimental group received instruction using the PBL-based guidebook, while the control group was taught using conventional methods. Effectiveness was measured by observing students' learning creativity using an observation instrument comprising 12 indicators, including fluency, originality, elaboration, collaboration, and implementation.[19,20]

All data collection procedures in this study adhered to research ethics principles, including obtaining informed consent, maintaining confidentiality, and ensuring that participation was entirely voluntary. Respondents retained full rights to withdraw from the study at any time without any consequences. This research received formal approval from the relevant educational institutions, and all processes were conducted transparently, traceably, and accountably by scientific standards.

Data Analysis

The data analysis in this study was conducted by the four stages of the research process: needs analysis, product validation, user response testing, and effectiveness testing. At the needs analysis stage, descriptive statistics were used to categorize students' and teachers' responses regarding the urgency of developing a learning model integrated with digital literacy. Responses were grouped into five categories: Very Need (VN), Need (N), Fairly Need (FN), Not Need (NN), and Very Not Need (VNN). In the validation stage, the same descriptive method was used to analyze scores from eight expert validators (four media experts and four subject matter experts). Their assessments were categorized into five levels of feasibility: Very Feasible (VF), Fairly Feasible (FF), Not Feasible (NF), and Very Not Feasible (VNF). The scoring intervals were determined using the same statistical thresholds applied in the previous stage. This consistency enhances the transparency and replicability of the analysis. At the user response stage, responses from 80 vocational students and 16 teachers regarding the usability and practicality of the guidebook were analyzed using the same descriptive technique. Categories used include Very Good (VG), Good (G), Fairly Good (FG), Not Good (NG), and Very Not Good (VNG). These classifications provided clear and structured feedback to assess user satisfaction and product usability. The classification was based on the ideal mean (Mi) and standard deviation (SDi), with score intervals and corresponding categories presented in table 3.

Table 3. Interval Score and Category Determination Framework			
Interval score	**Needs Analysis**	**Validation**	**User Response**
M>Mi+1,5 Sdi	Very Need	Very Feasible	Very Good
Mi+0,5 SDi<M≤Mi+ 1,5 SDi	Need	Feasible	Good
Mi-0,5 SDi<M≤Mi+ 0 SDi	Fairly Need	Fairly Feasible	Fairly Good
Mi-1,5 SDi<M≤Mi+(- 0,5 SDi M≤Mi-1,5Sdi	Not Need Very Not Need	Not Feasible	Not Good
M>Mi+1,5 Sdi	Very Need	Very Not Feasible	Very Not Good

Lastly, in the effectiveness testing phase, inferential statistical techniques were implemented. A paired-sample t-test was performed to analyze the change in creativity scores of students in the experimental group before and after the intervention. A normality test was conducted to ensure the data were normally distributed and suitable for parametric analysis. The outcome indicated a significant p-value of 0,000 ($p < 0,05$), which confirms the model's effectiveness in improving creativity. An independent sample t-test was performed to assess the difference in post-test scores between the two groups. The significance value was $p = 0,000$, which further validated that the problem-based learning integrated with a digital literacy approach provided to the experimental group was more effective than the conventional approach used with the control group. All tests were performed using SPSS, which was selected for its strong analytic capabilities, reliability, and considerable academic reputation.(36) A combination of descriptive and inferential statistical methods was employed, utilizing a trusted statistical package to ensure the results were accurate, valid, and reliable.

All phases of the study were conducted by the principles of research ethics, protecting the welfare, rights, and comfort of participants. In this study, informed consent was secured from respondents, including teachers, students, and experts, after briefing participants on the purpose and processes involved, as well as their expected roles. Participation was voluntary, and respondents were free to withdraw without any negative implications. There was, however, a preliminary study that was consented to, which included interviews, surveys, and focus group discussions. During the product validation and user response phases, expert and user feedback were gathered anonymously and used solely for model refinement. During the effectiveness testing stage, data were collected through observation and evaluation with the permission of the participating schools. All personal data was kept confidential, with no identifying information disclosed in reports or publications. Additionally, flexibility in participation was ensured, as the data collection was scheduled in a manner that did not disrupt learning activities. Together, these ethical aspects made sure that the research upheld the participants' dignity, privacy, and autonomy.

RESULTS

Preliminary Study: Identification of Learning Needs

The results of the survey conducted with 16 vocational students indicated that all four assessed aspects were categorized as Very Need. The detailed findings are presented in table 4.

Table 4. Survey Results on Learning Needs				
No	**Aspects**	**Number of Items**	**Mean Score**	**Category**
1	Media usage	4	16,10	Very need
2	Learning model implementation	4	16,25	Very need
3	Student learning outcomes	4	16,55	Very need
4	Support for instructional innovation	4	16,52	Very need
	Total/Average	16	16,42	Very need
Note: scoring based on a Likert scale from 1 (Very Not Need) to 5 (Very Need).				

Furthermore, the descriptive qualitative findings obtained from limited interviews and focus group discussions (FGDs) involving vocational teachers and students are summarized in table 5.

Table 5. Interview and FGD Results on EFI System Learning

Data source	Key Findings	Meaning
Teacher Interview	EFI material is considered abstract and difficult to understand without interactive visual media. [T1, T2, T3, and T4] Learning media is still manual and does not support real-world practice. [T2 and T4] One-way learning, lacking student exploration skills. [T1 and T2] Students' digital skills are still low. [T3]	Teachers expressed the need for learning that utilizes interactive digital media and problem-solving-based models to encourage students to be more active and understand concepts better.
Teacher and Student Focus Group Discussion	Students feel bored with lectures. [T1, T4] Difficulty understanding EFI sensors and actuators. [T2, T3, and T4] Rely solely on teacher explanations. [S6, S7, and S9] Desires project-based learning, videos, or simulations. [S1, S2, S3, S4]	Students desired more engaging learning models, based on real-world practice, and utilizing digital technologies such as video, animation, and independent exploration.

Note: T = Teacher and S = Student

Findings from the preliminary study indicate an urgent need for innovative learning approaches that go beyond conventional methods by actively engaging students through a problem-based learning (PBL) approach. In addition, the integration of digital literacy emerged as a critical requirement to support students in understanding abstract concepts and enhancing their learning creativity, particularly in mastering the complex competencies of the EFI system.

Design and Development

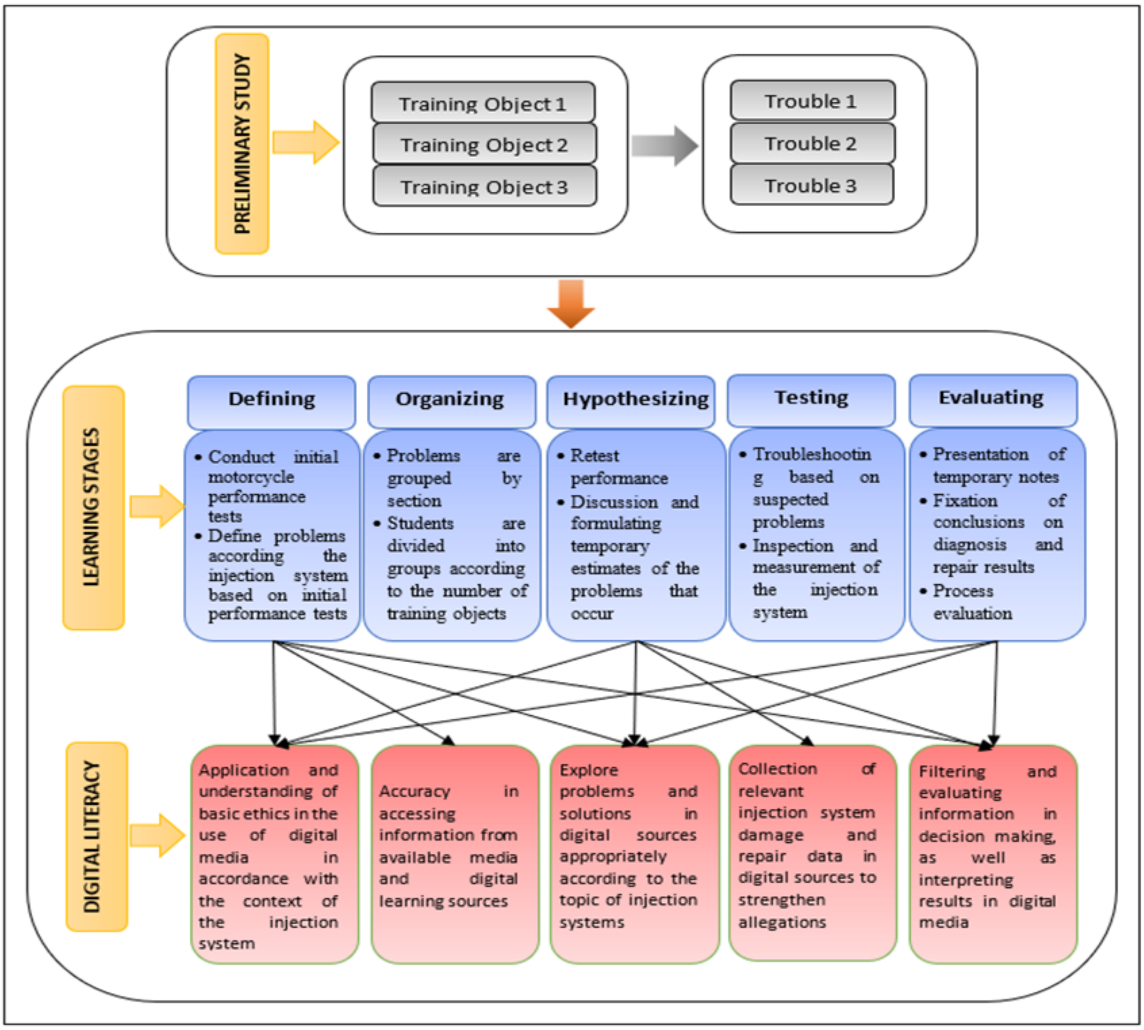

Figure 2. Problem-based Learning Steps Integrated with Digital Literacy in the EFI System Competency

The guidebook, which will serve as the development product, describes the steps in the developed learning model. In addition, the theory of the learning model, which consists of the understanding, foundation, benefits, and relevance of problem-based learning integrated with digital literacy, is also described. It aims to provide information to teachers as learning practitioners on the importance of problem-based learning models integrated with digital literacy, as well as the concept of the process. The steps of the problem-based learning model are described as follows: (1) Formulate a problem topic; (2) Organize the problem; (3) Formulate hypotheses; (4) Test hypotheses; and (5) Formulate problem-solving solutions.

Meanwhile, digital literacy that will be integrated into the syntax of problem-based learning consists of the following: (1) Application and understanding of basic ethics in the use of digital media by the learning context; (2) Accuracy in accessing information from available digital media and learning resources; (3) Exploration of problems and solutions in digital resources appropriately according to learning topics; (4) Collection of data according to the context in digital learning resources as support for solutions; and (5) Filtering and evaluation of information in decision making, as well as interpretation of results in digital media. The syntax of PBL integrated with digital literacy is presented in figure 2.

The development stage begins with preparation, which involves selecting materials (basic competencies, indicators of competency achievement, and lesson plans), creating integrated syntax, and preparing development products in the form of a learning model guidebook. The design of the problem-based learning model guidebook, integrated with digital literacy, is tailored to the theme of digital literacy. Text writing involves selecting the type of font, font size, spacing, and adopting a simple sentence structure. The elements of creating book media include image editing, context-adjusted cover design, book size, page count, paper type, chart editing, and colour selection. Completing the guidebook involves structuring its contents, printing, and binding the book. Figure 3 presents the cover design of the guidebook for problem-based learning models integrated with digital literacy.

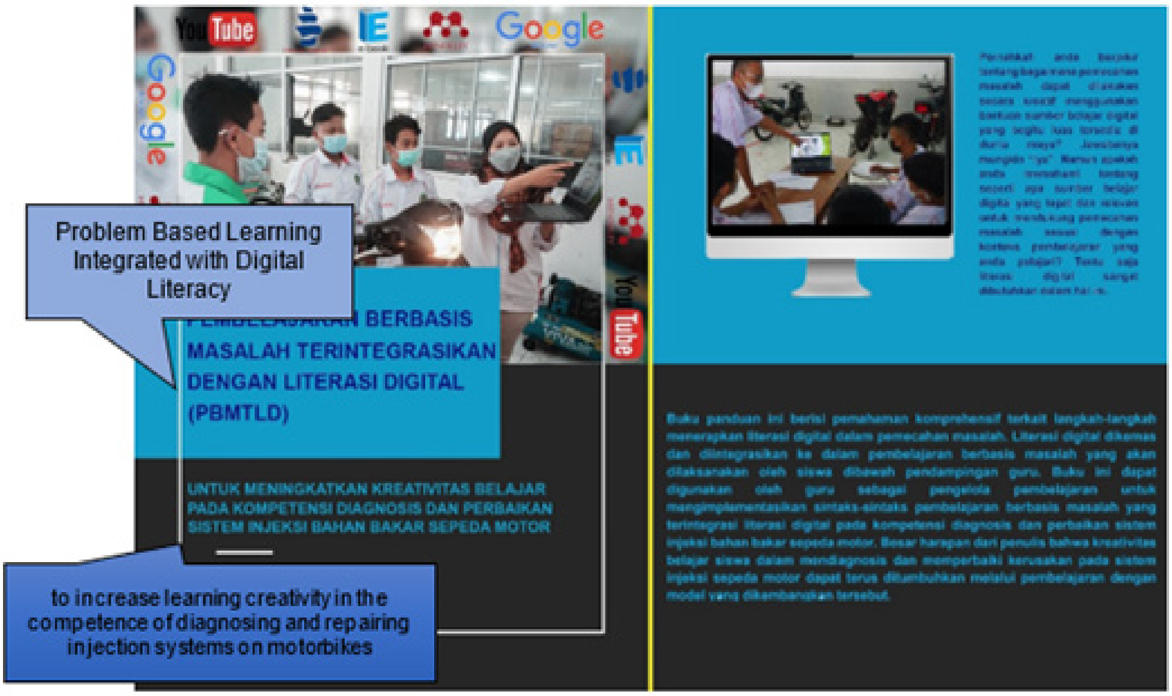

Figure 3. Cover of the Guidebook for a Problem-Based Learning Model Integrated with Digital Literacy

After the product has been developed, the next step is to conduct a feasibility validation test by asking for an expert assessment. Experts involved include material experts and media experts. Table 6 is a summary of the results of validation conducted by material experts, media, and learning practitioners. Based on the results of material validation, it can be concluded that the material's suitability to the learning context falls into the "feasible" category. The value of the suitability of learning steps, language, and format is in the "very feasible" category. The results of media validation obtained a feasibility value for design and visualization in the "very feasible" category. The feasibility value in terms of consistency and context suitability falls into the "feasible" category. Meanwhile, the assessment conducted by learning practitioners yielded results that fall into the very feasible category, as indicated by the video output, consistency, context suitability, and ease of use. Thus, it can be concluded that the feasibility of the developed product falls into the "very feasible" category for use and implementation.

Table 6. Result of Product Feasibility			
Expert	**Aspect**	**Score**	**Category**
Expert of Material (EMa)	Suitability of the material	4,22	Feasible
	Syntax suitability	4,40	Very Feasible
	Language and format	4,40	Very Feasible
Expert of Media (Eme)	Design and visualization	4,25	Very Feasible
	Consistency	4,00	Feasible
	Context suitability	4,00	Feasible
	Ease of use	4,67	Very Feasible

User Response Test Result

The results of the responses from teachers and students in the first stage are shown in table 7 below. The results of the user response analysis, conducted in the first stage of the product's implementation, were obtained in four aspects. All aspects of the teacher received a very good assessment. Meanwhile, for students, design and visualization, consistency, and language suitability are in the "good" category. At the same time, the aspect of ease of use received a "very good" assessment. Thus, in the first stage of implementation, a very good response to the developed product was obtained.

Table 7. Limited Scale Assessment Results					
No	**Aspect**	**Score**		**Category**	
		Teacher	**Student**	**Teacher**	**Student**
1	Design and visualization	4,67	4,00	Very Good	Good
2	Consistency	4,33	3,67	Very Good	Good
3	Context suitability	4,33	4,67	Very Good	Very Good
4	Ease of use	4,67	4,00	Very Good	Good

The results of the response test in the second stage of implementation are presented in table 8. All aspects, including design and visualization, consistency, ease of use, and language suitability, fall into the "very good" category in the assessment of teachers and students. Thus, the first stage of implementation received a very good response.

Table 8. Large Scale Assessment Results					
No	**Aspect**	**Score**		**Category**	
		Teacher	**Student**	**Teacher**	**Student**
1	Design and visualization	4,82	4,50	Very Good	
2	Consistency	4,38	4,33	Very Good	
3	Context suitability	4,41	4,67	Very Good	
4	Ease of use	4,82	4,50	Very Good	

Effectiveness Test Results

In this test, the hypothesis formulated is as follows. The results of the paired sample t-test are shown in table 9.

Table 9. Paired Sample t-Test Results			
Pair	**Mean Difference (Md)**	**t Statistic**	**p-value**
Experiment Pretest - Experiment Posttest	-17,250	24,949	0,000

Based on the results of the analysis above, the significance value in the experimental class pretest and posttest pair is 0,000. The significance value is smaller, with P < 0,05. Thus, there is a significant increase in student learning creativity after applying a problem-based learning model integrated with digital literacy. Then, the second analysis, related to the difference in learning creativity as measured in the questions, compares the average difference in learning creativity between the experimental posttest class and the posttest control class (table 10). Data analysis using the independent sample t-test assisted by SPSS V21, which has gone through the previous data normality test. In this test, the hypothesis formulated is as follows. The independent sample t-test results are shown in table 10. Based on the results of the analysis above, a significance value of 0,000 was obtained. The significance value is smaller, or P < 0,05. Thus, there is a significant difference in the average learning creativity of experimental posttest and posttest control class students.

Table 10. Independent Sample t-Test Results

Comparison	Mean Difference (Md)	t Statistic	p-value
Experiment Posttest - Control Posttest	6,625	8,981	0,000

DISCUSSION

The problem-based learning model product integrated with digital literacy (PBL-DL), developed in this study, aims to increase student learning creativity in the competency of diagnosing and repairing motorcycle injection systems, systematically packaged in an implementation guidebook. The model implementation guidebook aims to provide guidelines that can facilitate teachers in implementing the PBL-DL model to stimulate student learning creativity. In implementing the PBL-DL model, the guidebook is also supported by lesson plans and job sheets, which are also the result of development. The PBL-DL model is positively perceived by vocational learning practitioners, namely teachers and students. They jointly assessed the PBL-DL model book with very good criteria. This indicates that the model can be applied in learning, particularly to enhance student creativity in diagnosing and repairing motorcycle injection systems. Most teachers provided positive comments, stating that digital literacy is crucial for students in the current era of technological development.[36]

So far, vocational learning remains stuck in the same process as before, namely, relying on traditional methods and strategies. This illustrates a problem that shows that vocational learning has not developed and has not been adaptive to date.[2] Failing to adapt to developments can result in a gap in the skills students need to achieve. Learning in the era of digital transformation requires strong digital literacy.[37,38] Digital literacy is essential for better learning. It will help students gain a comprehensive understanding of the right digital technology to support learning achievement.[39] Strong digital literacy will be the foundation of students' mastery of built-in digital technology.[40] In addition, the ability to find appropriate and relevant digital learning resources is a key impact of digital literacy on students.[41] It is hoped that with good digital literacy followed by high mastery of digital technology, students can learn more effectively and efficiently than before.[42] Additionally, the integration of digital learning resources accessible through digital technology can provide broad and comprehensive insights and learning experiences.[14]

On the other hand, teachers also responded to problem-based learning, stating that it is very good to implement. Problem-based learning can provide students with a sense of meaning in their learning.[43] In addition, the inseparability of life from problems makes problem-based learning particularly effective when applied in vocational learning.[44,45] Problem-based learning is highly relevant to these competencies, especially in diagnosing and repairing motorcycle injection systems.[17] Teachers strongly agree that a comprehensive understanding of relevant technology and learning resources is integrated into the problem-solving process in learning. Teachers agree to the integration of digital literacy in problem-solving based on various factors. Efficiency and effectiveness in problem-solving are the primary reasons why teachers agree to integrate digital literacy.[14,46] In addition, through learning with digital literacy integration, students can gain a broad overview of learning resources that are useful in solving problems, especially complex ones.[33] Thus, teachers' perception of the feasibility of a model that embeds digital literacy is a significant signal of the shift towards learning processes aligned with current developments.

The feasibility of digital literacy applied to problem-based learning is supported by previous relevant research. The research concluded that digital literacy is highly effective when applied to learning, particularly in vocational education.[16,47] The number of competencies that involve sub-competencies in analysing complex system damage is the reason problem-solving is not limited only to solving existing problems; the depth and meaningfulness of the problem-solving process are also important aspects that students must experience. This is the feasibility of digital literacy in assisting problem-solving, as it will provide a comprehensive perspective on selecting appropriate and extensive learning resources.[48]

Other research reinforces the appropriateness of digital literacy in vocational learning. The research illustrates the low level of mastery of digital technology as a learning support.[49,50] In the case of a low level of mastery of digital technology, the study revealed that teachers' awareness of the presence of digital technology that can support learning still needs improvement. In addition, teachers' understanding of technology and digital learning resources still needs to be improved.[2,49,51,52] Thus, a learning innovation that can instil digital literacy in teachers' learning is urgently needed. Hence, the development of PBL-DL is very feasible for application in vocational learning, one of which is the competency of diagnosing and repairing injection systems.

The orientation of implementing problem-based learning, integrated with digital literacy, is to achieve student learning outcomes. However, on the other hand, this orientation is crucial in developing other essential skills for learning, particularly as the foundation for the learning process.(11) Learning to be creative is a vital skill for students to develop in their academic pursuits. Learning creativity will affect student stimulation in applying learning innovations. Learning is crucial for improvement and enhancement to increase the effectiveness of, thereby maximising competency.(19,53)

In the implementation of the PBL-DL model in the competency of diagnosing and repairing motorcycle injection systems, it has been proven that the model is effective in increasing student learning creativity. The effectiveness trial showed that the class that implemented the PBL-DL model proved to have higher student learning creativity than the class that used the same learning model as before. The creativity is evident in the students' fluency and flexibility in thinking and carrying out practical activities. In addition, the discovery of appropriate problem formulation ideas, followed by extensive solutions, is a visible part of learning creativity. Innovation in the form of solutions for repairing motorcycle injection systems is also seen in most students.

The effectiveness of the PBL-DL model in enhancing student learning and creativity demonstrates that the model is highly feasible for application in learning, particularly in the competency of diagnosing and repairing motorcycle injection systems. Several key factors significantly impact effectiveness. The integration of a comprehensive understanding of various learning resources that offer efficiency and effectiveness in problem-solving is a crucial aspect of enhancing learning creativity.(33,54) This is what digital technology can provide: a wide range of learning resources supported by strong digital literacy. Additionally, the nature of digital media, which enables the transformation of abstract systems into reality, is also a significant factor influencing the growth of student learning and creativity.(55)

Despite the promising findings, this study has several limitations. First, the implementation and testing were limited to EFI diagnostic competencies in motorcycle systems, which may not fully represent the model's applicability across other vocational domains or broader automotive systems. Second, the duration of the intervention was relatively short, which may have limited the long-term observation of creativity development. Third, students' digital literacy levels varied, which could have influenced the consistency of outcomes. Therefore, future research is recommended to apply the PBL-DL model in diverse vocational settings and over more extended periods to evaluate its sustained impact. It is also recommended to integrate initial digital literacy training before implementing PBL-DL to ensure more equitable engagement and outcomes across student groups.

CONCLUSIONS

This study successfully developed a Problem-Based Learning model integrated with Digital Literacy (PBL-DL) to enhance students' creativity in diagnosing EFI systems. The model was systematically designed, validated by experts, and implemented through a structured development process. Findings confirmed that the PBL-DL model significantly improved students' creative thinking, particularly in fluency, originality, and elaboration. Expert validation and user responses from both teachers and students categorized the model as highly feasible and very good in terms of usability, practicality, and content relevance. The model also demonstrated effectiveness in fostering student engagement and supporting system-based problem-solving in complex technical contexts. These results affirm that the PBL-DL model meets its intended objective and can serve as a viable instructional framework in vocational education. It holds strong potential for replication and adaptation in other domains that require creativity and digital competence.

BIBLIOGRAPHIC REFERENCES

1. Kurniawan R, Jaedun A, Mutohhari F, Kusuma WM. The Absorption of Vocational Education Graduates in The Automotive Sector in The Industrial World. J Educ Technol. 2021;5(3):482–490. doi: 10.23887/jet.v5i3.35365.

2. Mutohhari F, Sutiman S, Nurtanto M, Kholifah N, Samsudin A. Difficulties in implementing 21st century skills competence in vocational education learning. Int J Eval Res Educ. 2021;10(4):1229–36.

3. Clark L, Winch C. Vocational Education : International Approaches, Developments and Systems. New York: Routledge; 2007.

4. Fadhilah Makunti J, Widjanarko D. Increasing vocational school students' competency of automotive brake system by implementing diagnostic problem-based e-jobsheet. In: ICoVEMAT. Automotive Engineering Education, UniversitasNegeri Semarang, Indonesia: Institute of Physics Publishing; 2019. p. 1–10. doi: 10.1088/1742-6596/1273/1/012004.

5. Sutiman S, Sofyan H, Arifin Z, Nurtanto M, Mutohhari F. Industry and Education Practitioners' Perceptions Regarding the Implementation of Work-Based Learning through Industrial Internship (WBL-II). Int J Inf Educ Technol. 2022;12(10):1090–7. doi: 10.18178/ijiet.2022.12.10.1725.

6. Nasrudi M, Pardjono, Efendi A, Noviansyah W. Case study of electronic fuel injection competence acquisition of students at SMK PGRI 1 Ngawi. In: Journal of Physics: Conference Series. 2021. p. 1–9. doi: 10.1088/1742-6596/1833/1/012070.

7. Ag Damit MA, Omar MK, Mohd Puad MH. Issues and challenges of outcome-based education (OBE) implementation among Malaysian vocational college teachers. Int J Acad Res Bus Soc Sci. 2021;11(3):1–14. doi: 10.6007/ijarbss/v11-i3/8624.

8. Denton T. Advanced Automotive Fault Diagnosis. Second. Amsterdam: Elsevier; 2006.

9. Jabarullah NH, Iqbal Hussain H. The effectiveness of problem-based learning in technical and vocational education in Malaysia. Educ Train. 2019;61(5):552–67. doi: 10.1108/ET-06-2018-0129.

10. Jonassen DH. Learning to Solve Problems. San Francisco: Pfeiffer; 2004.

11. Nurtanto M, Sofyan H, Fawaid M, Rabiman R. Problem-based learning (PBL) in industry 4.0: Improving learning quality through character-based literacy learning and life career skill (LL-LCS). Univers J Educ Res. 2019;7(11):2487–94. doi: 10.13189/ujer.2019.071128.

12. Haryanto, Kusuma WM, Mutohhari F, Nurtanto M, Suyitno S. Innovation Media Learning: Online Project-Based Learning (O-PBL) on Drawing Competence in Automotive Engineering Using Video on YouTube [Internet]. Vol. 2111, Journal of Physics: Conference Series. 2021. doi: 10.1088/1742-6596/2111/1/012020.

13. Kassymova G, Akhmetova A, Baibekova M, Kalniyazova A, Mazhinov B, Mussina S. E-learning environments and problem-based learning. Int J Adv Sci Technol. 2020;29(7 Special Issue):346–56.

14. Perdana R, Jumadi J, Rosana D, Riwayani R. The online laboratory simulation with concept mapping and problem based learning (Ols-cmpbl): Is it effective in improving students' digital literacy skills? Cakrawala Pendidik. 2020 Jun;39(2):382–94. doi: 10.21831/cp.v39i2.31491.

15. Wongsila S, Yuenyong C. Enhancing grade 12 students' critical thinking and problem-solving ability in learning of the STS genetics and DNA technology unit. J Educ Gift Young Sci. 2019;7(2):215–35. doi: 10.17478/jegys.549005.

16. Nurtanto M, Nurhaji S, Widjanarko D, Wijaya MBR, Sofyan H. Comparison of scientific literacy in engine tune-up competencies through guided problem-based learning and non-integrated problem-based learning in vocational education. In: Journal of Physics: Conference Series. 2018. p. 1–7. doi: 10.1088/1742-6596/1114/1/012038.

17. Nurtanto M, Arifin Z, Sofyan H, Warju W, Nurhaji S. Development of model for professional competency assessment (Pca) in vocational education: Study of the engine tune-up injection system assessment scheme. J Tech Educ Train. 2020;12(2):34–45. doi: 10.30880/jtet.2020.12.02.004.

18. Nurtanto M, Fawaid M, Sofyan H. Problem Based Learning (PBL) in Industry 4.0: Improving Learning Quality through Character-Based Literacy Learning and Life Career Skill (LL-LCS). In Department of Mechanical Engineering Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia: IOP Publishing Ltd; 2020. doi: 10.1088/1742-6596/1573/1/012006.

19. Tan O-S. Problem Based Learning and Creativity. Singapore: Cengage Learning Asia Pte Ltd; 2009.

20. Piirto J. Creativity for 21st Century Skills: How to Embed Creativity into the Curriculum. Netherlands: Sense Publishers; 2011.

21. Farida RN, Utomo DP, Zukhrufurrohmah Z. The effectiveness of problem based learning in terms of creativity and learning outcomes. Math Educ J. 2020;4(2):1–14. doi: 10.22219/mej.v4i2.12277.

22. Piirto J. Understanding Creativity. Scottsdale, AZ: Great Potential Press; 2004.

23. Tūtlys V, Spöttl G. Disruption of qualifications in manufacturing: challenges and prospects. Eur J Train Dev. 2021;16(06):1-13. doi: 10.1108/EJTD-07-2020-0121.

24. Zhou C, Purushothaman A. The need to foster creativity and digital inclusion among women users in developing context-addressing second order digital divide in online skills. Int J Emerg Technol Learn. 2015;10(3):69–74. doi: 10.3991/ijet.v10i3.4248.

25. Akhter A, Anwarul Islam KM, Karim MM, Bin Latif W. Examining determinants of digital entrepreneurial intention: A case of graduate students. Probl Perspect Manag. 2022;20(3):1–14. doi: 10.21511/ppm.20(3).2022.13.

26. Rabiman R, Sudira P, Sofyan H, Nurtanto M. Practical Learning Media in Subject Maintenance of Chassis and Power (MCP) Based Online: Simple Learning Using Videos on YouTube. Int J Interact Mob Technol. 2021;15(3):130–45.

27. Mutohhari F, Sudira P, Nurtanto M. Automotive Engineering Drawing Learning: Effective Online Learning Using Autocad Application. J Educ Technol. 2021;5(2):214–9. doi: 10.23887/jet.v5i2.33197.

28. Astuti M, Arifin Z, Nurtanto M, Mutohhari F, Warju W. The maturity levels of the digital technology competence in vocational education. Int J Eval Res Educ [Internet]. 2022 [cited 2022 Jan 18];11(2):596-603. doi: 10.11591/ijere.v11i2.22258.

29. Fletcher J, Everatt J, Mackey J, Fickel LH. Digital Technologies and Innovative Learning Environments in Schooling: A New Zealand Experience. New Zeal J Educ Stud. 2020;55(1):91–112. doi: 10.1007/s40841-020-00156-2.

30. Jatmoko D, Suyitno S, Rasul MS, Nurtanto M, Kholifah N, Masek A, et al. The Factors Influencing Digital Literacy Practice in Vocational Education: A Structural Equation Modeling Approach. Eur J Educ Res. 2023;12(2):1109–21. doi: 10.12973/eu-jer.12.2.1109.

31. Falloon G. From digital literacy to digital competence: the teacher digital competency (TDC) framework. Educ Technol Res Dev [Internet]. 2020;68(5):2449–72. https://doi.org/10.1007/s11423-020-09767-4

32. Polizzi G. Digital literacy and the national curriculum for England: Learning from how the experts engage with and evaluate online content. Comput Educ. 2020;152:103859. doi: 10.1016/j.compedu.2020.103859.

33. Frank T, Castek J. From digital literacies to digital problem solving: Expanding technology-rich learning opportunities for adults. J Res Pract Adult Literacy, Second Basic Educ. 2017;4(2):66–70.

34. Akker J van den, Bannan B, Kelly AE, Nieveen N, Plomp T. An Introdution to Educational Design Research. East China Normal University. 2007. 129 p. doi: 10.26209/ijea21n2.

35. Rahmawati Y, Hadinugrahaningsih T, Ridwan A, Palimbunga US, Mardiah A. Developing the critical thinking skills of vocational school students in electrochemistry through STEM - Project-based learning (STEM-PjBL). In: AIP Conference Proceedings. 2021. p. 1–7. doi: 10.1063/5.0041915.

36. Mardapi D. Pengukuran, Penilaian, dan Evaluasi Pendidikan. Yogyakarta: Mitra Cendekia Press; 2012.

37. Sharma P. Digital Revolution of Education 4.0. Int J Eng Adv Technol. 2019;9(2):3558–64. doi: 10.35940/ijeat.a1293.129219.

38. Sudira P. TVET Abad XXI Filosofi, Teori, Konsep, dan Strategi Pembelajaran Vokasional. Ed.2, Cet. Hartono, editor. UNY Press. Yogyakarta: UNY Press; 2017. 295 p.

39. Jones RH, Hafner CA. Understanding Digital Literacies: A Practical Introduction. Understanding Digital Literacies: A Practical Introduction. 2012. doi: 10.4324/9780203095317.

40. Erstad O, Flewitt R, Meibauer BK, Pereira iris SP. The Routledge Handbook of Digital Literacies in Early Childhood. The Routledge Handbook of Digital Literacies in Early Childhood. 2019. doi: 10.4324/9780203730638.

41. Spante M, Hashemi SS, Lundin M, Algers A. Digital competence and digital literacy in higher education research: Systematic review of concept use. Vol. 5, Cogent Education. 2018. p. 1–21. doi: 10.1080/2331186X.2018.1519143.

42. Reddy P, Sharma B, Chaudhary K. Digital literacy: A review of literature. Int J Technoethics. 2020;11(2):1–16. doi: 10.4018/IJT.20200701.oa1.

43. Jonassen DH. Leraning to Solve Problems: A Handbook for Designing Problem-Solving Learning Environments. New York: Routledge; 2011.

44. Ramadhani R, Umam R, Abdurrahman A, Syazali M. The effect of flipped-problem based learning model integrated with LMS-google classroom for senior high school students. J Educ Gift Young Sci. 2019;7(2):137–58. doi: 10.17478/jegys.548350.

45. Putri AU, Rusyati L, Rochintaniawati D. The Impact of Problem-Solving Model on Students' Concept Mastery and Motivation in Learning Heat Based on Gender. J Sci Learn. 2018;1(2):71–6. doi: 10.17509/jsl.v1i2.9793.

46. Laar E v., Deursen AJAM van, Dijk J v., Haan J d. The Relation Between 21st-Century Skills and Digital Skills: A systematic Literature Review. Comput Human Behav. 2017;72:577–88. doi: 10.1016/j.chb.2017.03.010.

47. Fernández YO. Digital Skills and Digital Literacy: New Trends in Vocational Training. Int J Early Child Spec Educ. 2020 Jun;12(1):370–7. doi: 10.9756/INT-JECSE/V12I1.201016.

48. Setuju S, Surjono HD, Dwiningrum D, Triyono MB, Muhtadi A, Widowati A. Digital Literacy Competencies of Mechanical Engineering Vocational Education Teacher Candidates. Turkish J Comput Math Educ. 2021;12(6):2119–24. doi: 10.17762/turcomat.v12i6.4817.

49. Astuti M, Arifin Z, Mutohhari F, Nurtanto M. Competency of Digital Technology: The Maturity Levels of Teachers and Students in Vocational Education in Indonesia. J Educ Technol. 2021;5(2):254–62. doi: 10.23887/jet.v5i3.35108.

50. Rabiman R, Sudira P, Sofyan H, Nurtanto M. Practical Learning Media in Subject Maintenance of Chassis and Power (MCP) Based Online: Simple Learning Using Videos on YouTube. Int J Interact Mob Technol. 2021;15:130–45. doi: https://doi.org/10.3991/ijim.v15i03.14943.

51. Kholifah N, Kurdi MS, Nurtanto M, Mutohhari F, Fawaid M, Subramaniam TS. The role of teacher self-efficacy on the instructional quality in 21st century: A study on vocational teachers, Indonesia. Int J Eval Res Educ. 2023;12(2):998–1006.

52. Nurtanto M, Widjanarko D, Sofyan H, Rabiman R, Triyono MB. Learning by creating: Transforming automotive electrical textual material into visual animation as a creative learning products (clp). Int J Sci Technol Res. 2019;8(10):1634–42.

53. Kholifah N, Sofyan H, Pardjono P, Sudira P, Nurtanto M. Explicating the Experience of Beginner Vocational Teachers. TEM J [Internet]. 2021;10(2):719–23. doi: 10.18421/TEM102-28.

54. Jaedun A, Nurtanto M, Mutohhari F, Saputro IN, Kholifah N. Perceptions of vocational school students and teachers on the development of interpersonal skills towards Industry 5.0. Cogent Educ [Internet]. 2024;11(1):1–20. doi: 10.1080/2331186X.2024.2375184.

55. van Laar E, van Deursen AJAM, van Dijk JAGM, de Haan J. The Relation between 21st-Century Skills and Digital skills: A Systematic Literature Review. Comput Human Behav. 2017;72(12):577–88. doi: 10.1016/j.chb.2017.03.010.

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