Al-Ishlah: Jurnal Pendidikan
Vol.17, 2 (June, 2025), pp. 3612-3622
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v17i2.6699

Designing PBL-Based Mobile Learning: A Needs Analysis for Enhancing 21st Century Skills in Vocational Schools

Yolanda Idha Fitri[1], Yeka Hendriyani [2], Muhammad Giatman[3], Resmi Darni[4]

[1] Universitas Negeri Padang, Padang, Indonesia; yolandaif28@gmail.com
[2] Universitas Negeri Padang, Padang, Indonesia; yekahendriyani@ft.unp.ac.id
[3] Universitas Negeri Padang, Padang, Indonesia; giatman@ft.unp.ac.id
[4] Universitas Negeri Padang, Padang, Indonesia; resmidarni@ft.unp.ac.id

ARTICLE INFO

Keywords:

mobile learning;
problem-based learning;
21st century skills;
vocational high school

Article history:

Received 2024-12-23
Revised 2025-01-16
Accepted 2025-06-30

ABSTRACT

Advancements in information and communication technology have significantly transformed educational practices, including those in vocational high schools. Preparing students with 21st-century competencies—such as creativity, critical thinking, collaboration, and communication—has become increasingly essential, particularly in the digital era. This study aimed to assess the need for developing a mobile learning application using a problem-based learning (PBL) approach for the static routing topic within the Network Infrastructure Administration course at vocational high schools (SMK). The research involved both students and teachers as respondents to identify learning gaps, assess student competencies, and determine the desired features for an effective mobile learning tool. Findings revealed that a mobile learning solution incorporating the PBL approach holds significant potential to enhance students' understanding of static routing concepts. The analysis indicated that learners struggle with abstract technical content and benefit from interactive and contextualized learning strategies. The study highlights that mobile learning applications designed with PBL principles can bridge existing instructional gaps by fostering self-directed learning and critical thinking. Key considerations for development include accessibility, engaging interactive features, and integration of problem-solving tasks aligned with real-world scenarios.

Corresponding Author:
Yeka Hendriyani
Universitas Negeri Padang, Padang Indonesia; yekahendriyani@ft.unp.ac.id

1. INTRODUCTION

In the era of the Fourth Industrial Revolution, education played a pivotal role in preparing graduates to be equipped with essential 21st-century competencies—critical thinking, collaboration, communication, and creativity. These skills are fundamental for students to successfully adapt to rapid technological advancements and the evolving demands of the modern workforce (Putriani & Hudaidah, 2021). Within the context of Vocational High Schools (SMKs), the emphasis on skills-based learning has

become increasingly significant, particularly in specialized areas such as network technology. Mastery of core technical concepts like static routing is not only integral to students' academic development but also crucial for enhancing their employability and readiness for future careers in the digital and technological sectors (Hastutiningsih et al., 2024).

Despite the increasing integration of technology in education, the adoption of mobile learning in vocational schools remains inconsistent and limited. Many institutions face challenges related to infrastructure, teacher readiness, and the alignment of mobile learning tools with specific vocational competencies (Wardaini, 2021). This highlights the need for targeted research and development to address these gaps and create effective learning solutions tailored to vocational contexts.

One approach that has proven effective in fostering 21st-century abilities is Problem-Based Learning (PBL). By engaging students in solving real-world issues, PBL promotes critical thinking, collaborative abilities, and practical application of knowledge (Rerung et al., 2017). This makes PBL particularly well-suited for teaching technical concepts like static routing, as it encourages students to analyze complex scenarios, collaborate to develop solutions, and apply theoretical knowledge to practice. Integrating PBL with mobile learning offers additional benefits, such as flexibility, interactivity, and access to resources anytime and anywhere, which are critical for modern learners.

Furthermore, mobile learning has the potential to aid in the growth of specific 21st-century abilities. For instance, it enhances critical thinking by providing interactive simulations and problem-solving tasks, fosters collaboration through digital communication tools, and nurtures creativity by offering customizable learning environments. These features align closely with the demands of vocational education, where students must be prepared for a technology-driven workforce.

A crucial step in developing an effective PBL-based mobile learning system for static routing is conducting a comprehensive needs analysis. This process helps identify gaps between students' current competencies and the expected learning outcomes, while also outlining the technical and pedagogical requirements needed for successful implementation. By understanding these factors, educators can design a learning platform that addresses common challenges in vocational education and maximizes the benefits of mobile technology integration (Wardaini, 2021).

This research aims to analyze the needs for developing PBL-based mobile learning on static routing material in vocational schools. By addressing these needs, the study seeks to produce a mobile learning design that enhances students' mastery of static routing while simultaneously cultivating 21st-century skills. Beyond the immediate scope, this research underscores the broader implications for vocational education, highlighting the potential of technology-driven pedagogies to prepare students for the demands of an evolving workforce in the digital era.

It is commonly acknowledged that Problem-Based Learning (PBL) is a successful teaching strategy for fostering 21st-century skills (Barrows, 1986). Recent studies have shown that integrating PBL with mobile learning improves pupils' engagement, the ability to think critically and solve problems (Kusumawardani & Aminatun, 2024). Furthermore, mobile learning facilitates flexible and context-aware learning, allowing vocational students to access resources and collaborate beyond the classroom (Purba et al., 2024). This study builds upon these frameworks by examining how a PBL-based mobile learning design can enhance 21st-century skills in vocational education, particularly in resource-constrained environments.

This study is grounded in the theories of PBL, mobile learning, and 21st-century skills. The PBL framework, as conceptualised by Barrows (1986), emphasizes student-centered learning through real-world problem-solving. Meanwhile, mobile learning theory (Nadzeri et al., 2023) highlights the role of technology in creating personalized, ubiquitous learning experiences. Additionally, the 21st-century skills framework (Thornhill-Miller et al., 2023) outlines key competencies such as collaboration, creativity, and digital literacy, which are essential for vocational students in today's workforce. By integrating these theoretical perspectives, this study offers a comprehensive analysis of how PBL-based mobile learning is able to assist skill development in vocational education.

2. METHODS

The preliminary research in this study used Plomp's model. The procedure of action taken for this study can be seen in Table 1.

Table 1. Preliminary research procedure of the Plomp development model.

Phase	Focus	Activity
Preliminary Research	Needs and context analysis, literature review	The results of the needs analysis, curriculum analysis, student analysis, material analysis, and literature review form the guidelines for the framework and the first blueprint or prototype I of the developed product.
Prototyping Phase	Focus on validity, practicality. Further prioritizes practicality and gradually moves towards effectiveness.	Prototypes are created in stages and will be piloted and amended according to the formative evaluation stage, which is carried out using professional judgment.
Assessment Phase	Practicality and effectiveness	Determine whether using the product is efficient and practical and whether people want to use it.

The instruments used in this study underwent a thorough validation process to ensure their relevance, clarity, and reliability. Subject matter experts were consulted to review the instruments for content appropriateness and to verify that each item aligned with the study's objectives. Their feedback contributed significantly to refining the content and improving clarity. To ensure internal consistency, the instruments were subjected to reliability testing using Cronbach's Alpha, which confirmed their statistical soundness. Furthermore, the instruments were contextually adapted to suit the specific needs of vocational school settings. This adaptation was informed by both expert recommendations and responses from a pilot test, ensuring the tools were both pedagogically relevant and practically applicable.

During the prototyping phase, experts specializing in educational technology and vocational education played a pivotal role. Their insights helped guide refinements in the design and structure of the instruments, ensuring alignment with instructional goals and the realities of vocational learning environments. These contributions enhanced the practicality and relevance of the final prototype.

The study involved a purposive sample consisting of 150 students and 15 teachers from vocational schools. Data were analyzed using both quantitative and qualitative approaches. Descriptive and inferential statistical methods were applied to examine the quantitative data, allowing for a robust understanding of patterns and relationships. Meanwhile, qualitative data obtained from expert feedback were analyzed thematically to extract key insights and guide further improvements to the instruments and implementation strategies.

Table 2. Tools for Gathering Data

Analysis	Instrument	Reference
Learner Needs	Survey (Question Sheet)	Kurniati et al, 2021
Learners' Abdan 21 Skills	Questionnaire (Question Sheet)	Association, 2012; Festiyed et al, 2022; R. Kelley et al, 2019

There are 28 statements in the student needs questionnaire that use a Using a yes (1) and no (0) Guttman scale answer options. The student questionnaire on 21st Century Skills contained 33 assertions and used a five-point Likert Scale response option: firmly concur (5), concur (4), undecided (3), ever (2),

and never (1). The standard sheet for the method included 29 assertions that also used a Yes (1) and no (0) response on the Guttman Scale options. The last score of the survey was acquired using the following equation:

$$Final\ Score = \frac{Score\ Obtained}{Maximum\ Score} \times 100$$

3. FINDINGS AND DISCUSSION

This study was carried out when learning is in the early stages of study network infrastructure administration at the SMK level using the Plomp model of development. The phases of this study could be explained like this:

3.1 Learner Needs Analysis

This study's needs analysis was conducted to identify core issues that inform the development of new educational products, particularly those that address the enhancement of 21st-century skills among vocational school students. Data collection involved questionnaires distributed to students and interviews with Computer Network and Telecommunication Engineering (TJKT) teachers at SMKN 1 Sungai Penuh and SMKN 3 Sungai Penuh. Discussions focused on the instructional methods, learning models, systems, and teaching resources currently in use, and how these elements support or hinder the development of students' 21st-century competencies.

The results from teacher interviews revealed several key issues within the existing educational practices. First, printed textbooks remain the dominant learning resource in classrooms, despite their limited ability to engage students or foster higher-order thinking. Second, although teachers have supplemented printed materials with student worksheets (LKS) or presentation tools like PowerPoint, these resources do not explicitly integrate 21st-century skills such as critical thinking, collaboration, and problem-solving. Third, mobile learning tools—especially those developed to meet the specific needs of 21st-century education—are rarely used. Fourth, while some instructional models and strategies used by teachers align with the demands of modern learning, their implementation often lacks consistency or optimal execution. Lastly, students' 21st-century skill levels, including communication, creativity, and collaboration, remain relatively low. One teacher noted, "*We rely heavily on printed books, but they don't engage students much. The current resources are insufficient to develop their critical thinking or problem-solving skills*." Another added, "Integrating mobile learning could be beneficial, but we need training to effectively implement it."

Student feedback echoed these concerns. Based on the needs analysis survey, 92% of learners reported relying primarily on printed handbooks, while 81% stated that these handbooks alone were insufficient for meaningful learning. Furthermore, 83% of students expressed interest in trying mobile learning approaches grounded in problem-based learning, and 95% indicated a need for instructional tools that are both engaging and conceptually clear. These findings demonstrate a strong demand for educational media that are interactive, student-centered, and relevant to real-world problems.

To address the identified gaps, the development of a mobile learning tool tailored to the Class XI Network Infrastructure Administration course in vocational schools was proposed. This tool is designed around a problem-based learning (PBL) framework to enhance student motivation, strengthen critical thinking, and promote active engagement. Prior research supports the effectiveness of mobile and PBL-integrated learning in improving educational outcomes (Junita, 2023; Laili et al., 2019; Warsita, 2018). Problem-based learning fosters collaboration, creativity, and reflective problem-solving, encouraging students to work in teams and actively construct knowledge through authentic challenges (Arsanti & Subiantoro, 2021; Hotimah, 2020; Noer & Gunowibowo, 2018; Sucipto, 2017; Sudarman, 2000). This approach aligns with the core goals of 21st-century education, which aim to

develop learners into independent, lifelong thinkers who are adaptable and competitive in an increasingly complex and technology-driven world (Havid & Yulkifli, 2022; Hudha et al., 2017).

3.2 Challenges and Barriers

Despite its potential, the adoption of mobile learning and PBL is not without challenges. Teachers highlighted the need for training to familiarize themselves with mobile learning platforms. Technological limitations, such as inconsistent internet access and a lack of devices for all students, were also significant barriers. Additionally, there was some resistance to change among teachers and students accustomed to traditional methods. To overcome these challenges, collaboration with technology providers and structured training programs for teachers can be effective solutions. Pilot programs could also help build confidence and showcase the benefits of mobile learning to stakeholders.

Implementing PBL-based mobile learning in schools with different conditions requires tailored strategies. In schools with advanced digital infrastructure, the integration of mobile learning and PBL could proceed more smoothly with minimal technical barriers (Jeong et al., 2024). However, in schools facing technological constraints, such as inconsistent internet access and limited devices, careful planning is needed to ensure equitable access to resources (Alieto et al., 2024). Additionally, teachers must be supported through professional development programs that address both the technical aspects of mobile learning and the pedagogical strategies for effective PBL implementation (Tlili et al., 2024).

3.3 Analysis of Student Characteristics

Learner characteristics analysis is conducted to find out their initial characteristics as a basis for consideration in developing mobile learning. Each individual has different characteristics, so this analysis is important. Data on learners' characteristics were obtained through a questionnaire that covers elements of motivation, attitude, interest and learning style. The outcomes of every component are shown in Figure 1.

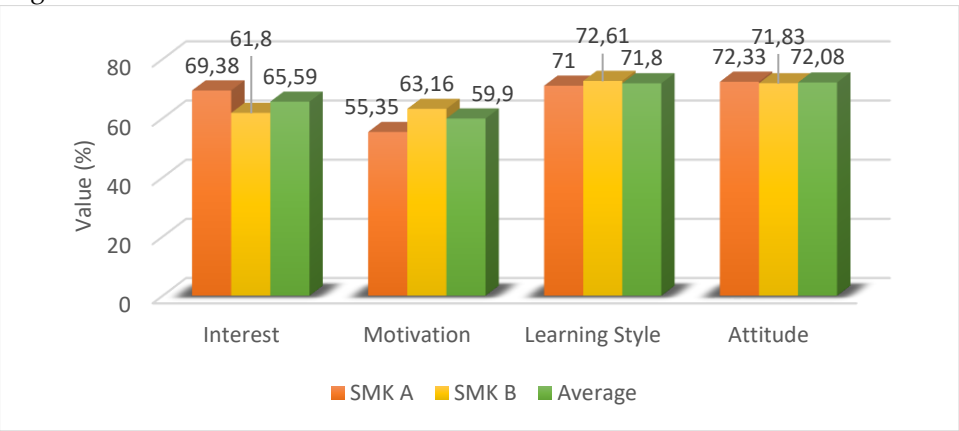

Figure 1. Results of Student Characteristics Analysis

Based on the analysis presented in Figure 1, the findings on student characteristics reveal that the highest mean score was recorded in the disposition aspect, with an average percentage of 72.08%. The learning style aspect followed closely with a mean score of 71.8%, both of which fall within the moderate category. The interest aspect showed a mean percentage of 65.59%, also categorized as sufficient. However, the learning motivation aspect had the lowest average score at 59.9%, placing it in the low category and indicating a clear need for improvement. These results highlight the importance of developing interactive and engaging educational tools—such as mobile learning platforms—that not only cater to various learning styles but also actively enhance students' motivation to learn.

This study differentiates itself from previous research by specifically focusing on the integration of mobile learning with PBL in vocational schools, an area that has been less explored. Unlike other

studies that emphasize general PBL applications or mobile learning individually, this research combines both to address the specific challenges faced by vocational school students in network infrastructure administration, thus offering a more targeted approach to improving 21st-century skills.

3.4 Broader Implications and Contextual Comparisons

Integrating PBL and mobile learning in vocational education can close the gap between 21st-century expectations and present educational methods. For instance, by moving away from traditional, print-based methods to interactive, technology-enhanced learning, students can better develop critical thinking and collaborative skills. Comparatively, regions with more advanced digital infrastructure may experience fewer challenges in implementation, while areas with limited access may require tailored approaches and additional support.

Furthermore, the applicability of these findings extends beyond the specific vocational schools studied. In low-resource environments, implementing mobile learning solutions may necessitate alternative strategies, such as offline-accessible content, community partnerships, or mobile-first pedagogical frameworks. By considering these diverse educational contexts, the proposed approach can be adapted to meet the needs of different vocational institutions, ensuring inclusivity and accessibility.

Overall, the findings provide a strong foundation for developing mobile learning solutions that are not only relevant to vocational education but also scalable across diverse educational settings. By addressing the identified gaps and challenges, this approach has the potential to transform vocational education and prepare students for the dynamic demands of the modern workforce.

Several research has explored the integration of Problem-Based Learning (PBL) and mobile learning in vocational education. A study by Ali et al. (2021) in Malaysia found that implementing PBL in mobile learning environments significantly improved students' problem-solving skills. Similarly, Gómez & Fernández (2020) in Spain reported that mobile learning enhances student collaboration in vocational training programs. These findings align with the findings of this investigation, which show that the combination of PBL and mobile learning effectively supports students in understanding complex technical concepts such as static routing. However, while studies conducted in developed countries emphasize the effectiveness of mobile learning, this research highlights additional challenges in vocational schools with limited digital infrastructure.

Unlike previous studies that primarily focus on cognitive and collaborative aspects of PBL, this research expands the discussion by examining how PBL-based mobile learning fosters digital literacy and technical problem-solving skills—critical competencies for vocational students in the era of Industry 4.0. Furthermore, while global studies have demonstrated the effectiveness of PBL in STEM and medical education, limited research has investigated its implementation in technical subjects such as networking and static routing within vocational schools. This study contributes to filling that gap by analyzing the specific needs and challenges associated with integrating mobile learning into technical vocational education.

Additionally, this research highlights key differences in implementation across contexts. Unlike studies from developed countries, where mobile learning adoption is primarily influenced by pedagogical strategies, this study reveals that success in vocational schools is also highly dependent on technological accessibility, teacher readiness, and institutional support. These findings underscore the importance of designing context-aware mobile learning solutions that accommodate varying levels of technological infrastructure and educator preparedness. By addressing these factors, the research offers insightful information about the broader implications PBL-based mobile learning for vocational education worldwide.

The instruments used to measure learners' 21st-century skills and other characteristics were validated through a rigorous process involving expert validation and reliability testing. The V of Aiken coefficient was used to assess the objects' validity, ensuring that they accurately reflected the targeted constructs. In light of the validation's findings, Aiken's V value for all items was above 0.7, indicating

that the instruments had good validity. Additionally, the reliability of the instruments was tested utilizing Cronbach's Alpha, which produced a 0.89 result for 21st-century skills and 0.85 for learner characteristics, indicating high internal consistency. The instruments' validity and dependability confirm that the data collected can be relied upon to inform the development of mobile learning solutions.

3.5 Analysis of Learners' 21st Century Skills

Learners' skills for the twenty-first century were obtained using a survey consisting of 33 assertions. Figure 2 below displays the analysis's findings.

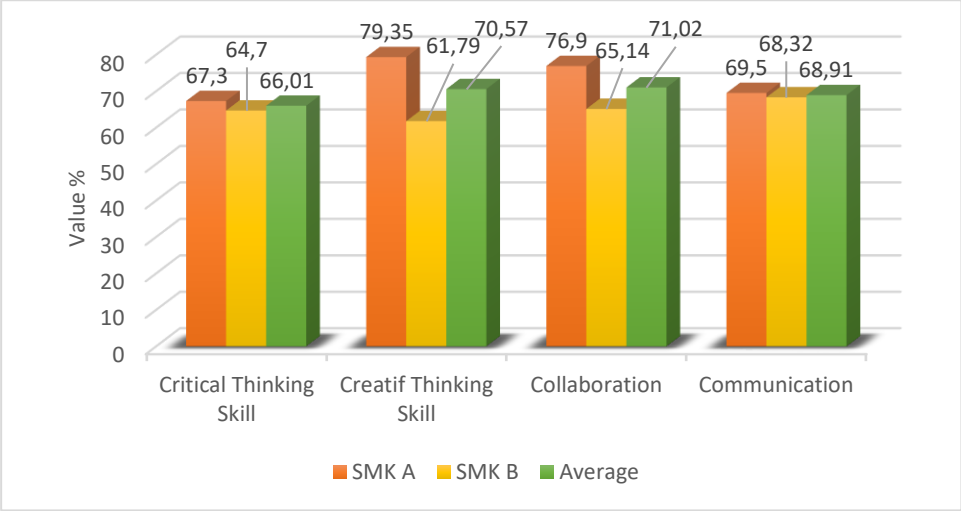

Figure 2. Analysis of Learners' 21st Century Competencies

The 21st century ability with communication receives the heighest average score, with an average percentage of 68,91%, which is classified as sufficient. Meanwhile, other skill aspects like the ability to think critically had an average proportion of 66,01%, abilities think creatively amounted to 70,57%, and collaboration skills reached 71,02%. The overall average of 21st century skills is 69,12%, with a sufficient category. Nevertheless, these skills need to be improved as they should bet a ghigher of better level (Varghese & M.N Mohamedunni Alias Musthafa, 2021). To improve 21st century skills, teaching materials based on learning models that can develop these skills are needed.

3.6 Analysis of Process Standards

Process standards are one of the aspects that must be examined in early studies. This standard aims to direct the application of efficient and successful learning to develop students' possibility, abilities, & self-reliance (Permendikbudristek, 2022). The process typically includes learning, arranging and implementation. The execution stage includes preparatory and core tasks that involve the use of models, media, educational materials and methods, and concluding exercises. The process's outcomes standards analysis is displayed in Figure 3.

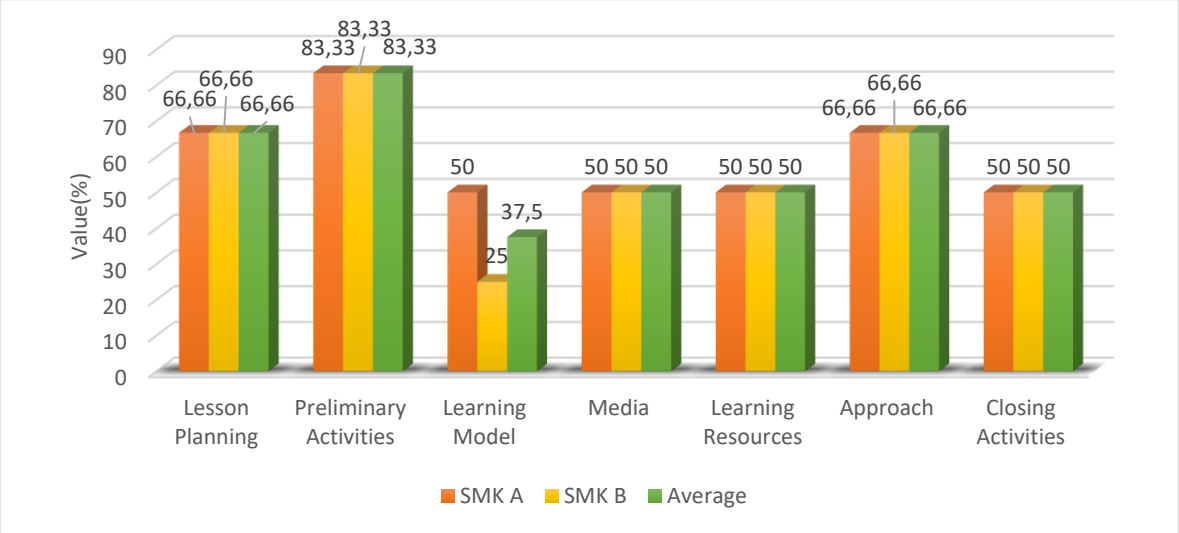

Figure 3. Results Analysis of Process Standards

Based on Figure 3, the analysis of the standard aspects of the process shows that the indicator with the highest average value is the indicator of preliminary activities, with an average value of 83.33%, which is included in the good category. In contrast, the indicator with the lowest score was the one using the learning model, which had 37.5% on average and was included in the actual poor class, but the learning resource indicator had a dismal category average score of 50%. Improvements are required because the examination of process standards reveals that the use of learning resources and the implementation of learning models in schools are not at their best. The choice of learning models acts as a methodical manual for teachers, assisting with the creation of lesson plans, instructional resources, instructional assistance, and instructional scenarios (Asrizal & Festiyed, 2020). Additionally, learning tools are crucial for assisting the learning process, and using good teaching resources can promote and ease student learning (Asrizal & Festiyed, 2020). Therefore, learning resources need to be integrated into the learning model to make the process of teaching and learning easier and ensure student-centred learning.

3.7 Concept Analysis and Theory

Student attitudes, motivation, and interest are among the learning outcomes that are positively impacted by the efficacy of problem-based learning models (Fauzan et al., 2017; Lintang et al., 2017; Nurliastuti et al., 2018; Rahmat, 2018; Rerung et al., 2017; Wulandari et al., 2023). Models of problem-based learning are equally pertinent for enhancing 21st-century abilities. Table 3 lists a few studies that demonstrate the benefits of problem-based learning approaches.

Table 3. Effect of the problem-based learning approach

Competence	Research
Creativity	Mayasari et al., 2016; Rahma Dhiyaul Imaroh et al., 2022; Suharyat et al., 2022; Yanuarni et al., 2021
Critical Thinking	amdalia Herzon et al, 2018; Hotimah, 2020; Muslim et al, 2015; Rahmawati et al, 2017; Salamiyah & Kholiq, 2020; Agnesa & Rahmadana, 2022; Yanuarni et al., 2021
Collaboration	Haryati & Wangid, 2023, Ilmiyatni et al., 2019, Mayasari et al., 2016; Suharyat et al., 2022; Tri Pudji Astuti, 2019; Yanuarni et al., 2021
Communication	Ashim et al., 2019; Haryati & Wangid, 2023; Mayasari et al., 2016; Suharyat et al., 2022; Tri Pudji Astuti, 2019; Yanuarni et al., 2021

Problem-based learning (PBL) aims to engage students with real-world challenges that require collaborative problem-solving, data analysis, and the exploration of relevant information (JiannWen &

Liao, 2024). This approach is widely recognized for its effectiveness in fostering creativity, collaboration, critical thinking, and higher-order cognitive skills. Additionally, PBL enhances students' independence, teamwork, and communication abilities, equipping them with essential competencies for academic and professional success (Ahsa & Arabia, 2024; Salamiyah et al., 2020). As such, this learning model is particularly well-suited to the field of network infrastructure administration, where it can significantly improve instructional quality and promote the development of 21st-century skills (Ahsa & Arabia, 2024).

4. CONCLUSION

Based on the findings of this study, the integration of mobile learning using a problem-based learning (PBL) approach shows significant potential in enhancing 21st-century skills among vocational school students. The analysis revealed that printed textbooks remain the dominant learning resource, with limited incorporation of 21st-century competencies such as critical thinking, collaboration, and digital literacy. Current instructional practices still lean heavily on traditional methods, and students' overall mastery of 21st-century skills was found to be at a moderate level (68.86%), signaling a pressing need for more dynamic and relevant learning models. Additionally, aspects of student motivation and engagement were found to be suboptimal, further emphasizing the urgency for instructional innovations tailored to the needs of modern learners.

To address these challenges, several key strategies are recommended. Curriculum development should prioritize the structured integration of PBL-based mobile learning to better align with the practical and evolving demands of vocational education. Learning materials must be designed to include real-world problem-solving tasks, digital competencies, and collaborative activities. Teacher professional development programs should also focus on strengthening educators' capacity to implement PBL methodologies and mobile learning tools effectively. Institutional support in the form of continuous training, mentoring, and accessible digital infrastructure is essential to facilitate this transition. From a policy standpoint, greater investment is needed to develop scalable and context-appropriate mobile learning platforms, alongside the establishment of policies that encourage their adoption in vocational settings.

While this study provides valuable insights, it is limited by its scope, focusing only on specific subjects within selected schools. Therefore, the generalizability of the findings is constrained. Future research should broaden its scope across various disciplines and institutions and adopt a longitudinal approach to assess the sustained impact of PBL-based mobile learning on academic achievement, employability, and workforce preparedness. Such research could offer a deeper understanding of how innovative instructional models contribute to educational transformation in the digital era. Overall, this study highlights the critical role of mobile learning and problem-based pedagogy in advancing vocational education and meeting the evolving demands of 21st-century learners.

Acknowledgements: The authors would like to thank Padang State University and the Institute for Development and Quality Assurance of Padang State University, for the Research Grant (Hibah PTM 2024), based on Decree Number 394/UN.35/LT/2024.

Conflicts of Interest: Identify and disclose any conflicts of interest. "No conflicts of interest are disclosed by the autors." Any personal circumstances or interests that can be interpreted as improperly influencing the depiction or interpretation of published study results must be identified and declared by the authors.

REFERENCES

Ahsa, A., & Arabia, S. (2024). Enhancing 21st century skills through integrated STEM education using project-oriented problem-based learning. *Geographia Technica, 53*(2), 421–430. https://doi.org/10.30892/gtg.53205-1217

Alieto, E., Abequibel-Encarnacion, B., Estigoy, E., & Balasa, K. (2024). Teaching inside a digital classroom: A quantitative analysis of attitude, technological competence and access among teachers across subject disciplines. *Heliyon, 10*(2), e24282. https://doi.org/10.1016/j.heliyon.2024.e24282

Arsanti, I. A., & Subiantoro, A. W. (2021). Pengembangan LKPD mobile learning berbasis Android dengan PBL untuk meningkatkan critical thinking materi lingkungan. *Jurnal Pendidikan Biologi, 10*(1), 24–31.

Asrizal, A., & Festiyed, F. (2020). Studi pendampingan pengembangan bahan ajar tematik terintegrasi literasi baru dan literasi bencana pada guru IPA Kabupaten Agam. *Jurnal Eksakta Pendidikan (JEP), 4*(1), 97. https://doi.org/10.24036/jep/vol4-iss1/431

Fauzan, M., Gani, A., & Syukri, M. (2017). Penerapan model problem based learning pada pembelajaran materi sistem tata surya untuk meningkatkan hasil belajar siswa. *Jurnal Pendidikan Sains Indonesia, 5*(1), 27–35.

Hastutiningsih, A. D., Sugiyono, S., Suyanto, S., & Ashyrnepesov, V. (2024). Evaluation of vocational education management in the era of the Fourth Industrial Revolution and Society 5.0 at SMKN 2 Pengasih. *Jurnal Pendidikan Teknologi dan Kejuruan, 30*(1), 51–61. https://doi.org/10.21831/jptk.v30i1.70013

Havid, M., & Yulkifli, Y. (2022). Efektifitas LKPD model inquiry based learning dengan pendekatan saintifik pada pembelajaran fisika abad 21. *Jurnal Penelitian Pembelajaran Fisika, 8*(1), 45. https://doi.org/10.24036/jppf.v8i1.116343

Hotimah, H. (2020). Penerapan metode pembelajaran problem based learning dalam meningkatkan kemampuan bercerita pada siswa sekolah dasar. *Jurnal Edukasi, 7*(3), 5. https://doi.org/10.19184/jukasi.v7i3.21599

Hudha, M. N., Aji, S., & Rismawati, A. (2017). Pengembangan modul pembelajaran fisika berbasis problem based learning untuk meningkatkan kemampuan pemecahan masalah fisika. *Science Education Journal (SEJ), 1*(1), 36–51. https://doi.org/10.21070/sej.v1i1.830

Jeong, D. W., Moon, H.-S., Jeong, S. M., & Moon, C. J. (2024). Digital capital accumulation in schools, teachers, and students and academic achievement: Cross-country evidence from the PISA 2018. *International Journal of Educational Development.* https://api.semanticscholar.org/CorpusID:268640039

JiannWen, H., & Liao, Y.-M. (2024). Application of problem-based learning in marketing studies combined with silver-haired business opportunities. *Thinking Skills and Creativity.* https://api.semanticscholar.org/CorpusID:270349337

Junita, W. (2023). Penggunaan mobile learning sebagai media dalam pembelajaran. *Prosiding Seminar Nasional Teknologi Pendidikan Pascasarjana UNIMED*, 602–609.

Kusumawardani, W., & Aminatun, T. (2024). PBL in blended learning design to increase critical thinking and problem-solving skills. *Jurnal Penelitian Pendidikan IPA, 10*(6), 3303–3308. https://doi.org/10.29303/jppipa.v10i6.7052

Laili, I., Ganefri, & Usmeldi. (2019). Efektivitas pengembangan e-modul project based learning pada mata pelajaran instalasi motor listrik. *Jurnal Imiah Pendidikan dan Pembelajaran, 3*(3), 306–315.

Lintang, A. C., Masrukan, M., & Wardani, S. (2017). PBL dengan APM untuk meningkatkan kemampuan pemecahan masalah dan sikap percaya diri. *Journal of Primary Education, 6*(1), 27–34.

Nadzeri, M. B., Musa, M., Meng, C. C., & Ismail, I. M. (2023). Interactive mobile technologies. *International Journal of Interactive Mobile Technologies, 17*(15), 135–154.

Noer, S. H., & Gunowibowo, P. (2018). Efektivitas problem based learning ditinjau dari kemampuan berpikir kritis dan representasi matematis. *Jurnal Penelitian dan Pembelajaran Matematika, 11*(2).

https://doi.org/10.30870/jppm.v11i2.3751

Nurliastuti, E., Dewi, N. R., & Priyatno, S. (2018). Penerapan model PBL bernuansa etnomatematika untuk meningkatkan kemampuan pemecahan masalah matematis dan motivasi belajar siswa. *Prisma, Prosiding Seminar Nasional Matematika, 1*, 99–104.

Permendikbudristek. (2022). *Peraturan Menteri Pendidikan Kebudayaan Riset dan Teknologi tentang Standar Proses pada Pendidikan Usia Dini, Jenjang Pendidikan Dasar dan Jenjang Pendidikan Menengah*. Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia Nomor 16 Tahun 2022, 1(69), 5–24.

Purba, S. W. D., Chao, H. C., Hwang, W. Y., & Tang, Y. Q. (2024). Empowering vocational students: Exploring mobile learning for sustainable high-level cognition in authentic contexts. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(8). https://doi.org/10.29333/ejmste/14917

Putriani, J. D., & Hudaidah, H. (2021). Penerapan pendidikan Indonesia di era Revolusi Industri 4.0. *Edukatif: Jurnal Ilmu Pendidikan, 3*(3), 830–838. https://doi.org/10.31004/edukatif.v3i3.407

Rahmat, E. (2018). Penerapan model pembelajaran problem based learning (PBL) untuk meningkatkan prestasi belajar siswa. *Jurnal Penelitian Pendidikan, 18*(2), 144–159. https://doi.org/10.17509/jpp.v18i2.12955

Rerung, N., Sinon, I. L., & Widyaningsih, S. W. (2017). Penerapan model pembelajaran problem based learning (PBL) untuk meningkatkan hasil belajar peserta didik SMA pada materi usaha dan energi. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni, 6*(1), 47–55. https://doi.org/10.24042/jpifalbiruni.v6i1.597

Salamiyah, Z., & Kholiq, A. (2020). Salamiyah. *Jurnal Edukasi, 9*(3), 342–348.

Sucipto, S. (2017). Pengembangan ketrampilan berpikir tingkat tinggi dengan menggunakan strategi metakognitif model pembelajaran problem based learning. *Jurnal Pendidikan (Teori dan Praktik), 2*(1), 77. https://doi.org/10.26740/jp.v2n1.p77-85

Sudarman. (2000). Problem based learning: Suatu model pembelajaran untuk mengembangkan dan meningkatkan kemampuan memecahkan masalah. In *Prosiding Seminar Nasional Pendidikan*, 68–73.

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, critical thinking, communication, and collaboration: Assessment, certification, and promotion of 21st century skills for the future of work and education. *Journal of Intelligence, 11*(3). https://doi.org/10.3390/jintelligence11030054

Tlili, A., Salha, S. S., Garzón, J., Denden, M., Kinshuk, Affouneh, S., & Burgos, D. (2024). Which pedagogical approaches are more effective in mobile learning? A meta-analysis and research synthesis. *Journal of Computer Assisted Learning, 40*, 1321–1346. https://api.semanticscholar.org/CorpusID:267774948

Varghese, J., & Musthafa, M. N. M. A. (2021). Investigating 21st century skills level among youth. *GiLE Journal of Skills Development, 1*(2), 99–107. https://doi.org/10.52398/gjsd.2021.v1.i2.pp99-107

Wardaini, S. (2021). Upaya meningkatkan prestasi belajar siswa melalui model problem based learning (PBL) pada pembelajaran IPA. *Unpublished Manuscript*.

Warsita, B. (2018). Mobile learning sebagai model pembelajaran yang efektif dan inovatif. *Jurnal Teknodik, 14*(1), 62–73. https://doi.org/10.32550/teknodik.v14i1.452

Wulandari, A., Parenrengi, S., & Tune, I. L. (2023). Penerapan model pembelajaran problem based learning untuk meningkatkan motivasi belajar siswa SMK. *Jurnal Pendidikan dan Profesi Keguruan, 2*(2), 225. https://doi.org/10.59562/progresif.v2i2.30424