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Adjustment of Mathematics Materials Based on STEM Approach to Improve Problem-Solving Skills

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Abstract

Background – The integration of STEM (Science, Technology, Engineering, and Mathematics) in education has become an important strategy to prepare students to face global challenges and the demands of the Industrial Revolution 4.0. In vocational education, especially in Pharmacy Vocational Schools, mathematics learning is expected to be more contextual and connected to professional practices so that students can develop analytical and problem-solving skills relevant to the pharmaceutical field.
Purpose – This study aims to examine the adjustment of pharmaceutical contextual mathematics material based on the STEM approach in improving the problem-solving abilities of Pharmacy Vocational School students.
Method/approach – This study employed a literature review method by analysing and synthesizing various scientific references related to STEM-based learning, contextual mathematics, and pharmaceutical vocational education published within the last five years. The collected literature was reviewed systematically to identify the implementation, benefits, and challenges of integrating STEM approaches into pharmaceutical mathematics learning.
Findings – The findings indicate that the application of mathematics materials integrated with pharmaceutical contexts, such as dosage calculations, formulation of pharmaceutical preparations, and laboratory analysis, significantly improves students' learning engagement, conceptual understanding, and problem-solving abilities. The STEM approach enables students to connect mathematical concepts with scientific and technological applications in pharmaceutical practice, thereby transforming mathematics from an abstract subject into a practical and meaningful analytical tool. In addition, STEM-based learning encourages critical thinking, collaboration, and active participation among students during the learning process.
Conclusions – This study concludes that the integration of STEM-based contextual mathematics materials in Pharmacy Vocational Schools can effectively enhance students' problem-solving skills and support the development of competencies needed in the pharmaceutical profession. The interdisciplinary STEM approach also helps bridge the gap between academic theory and workplace demands.
Novelty/Originality/Value – This study highlights the importance of integrating pharmaceutical contexts into STEM-based mathematics learning in vocational education, particularly in Pharmacy Vocational Schools. The study provides insights into how contextual and interdisciplinary learning can improve students' understanding, engagement, and readiness for professional practice in the pharmaceutical field.

Keywords: STEM Approach, Problem-Solving Skills, Pharmaceutical Mathematics

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INTRODUCTION

The development of the Industrial Revolution 4.0 and Society 5.0 has significantly transformed the educational landscape, particularly vocational education, which is expected to produce graduates equipped not only with technical competencies but also with critical thinking, creativity, collaboration, communication, and complex problem-solving abilities (Fathoni et al., 2020; Widana et al., 2021; Abdullah & Triwahyuni, 2024). Rapid advancements in science and technology require vocational education institutions to prepare adaptive human resources capable of responding to industrial changes and multidisciplinary workplace challenges (Bianome et al., 2025; Wantrilita & Rohaeti, 2025). In this context, STEM (Science, Technology, Engineering, and Mathematics) education has emerged as one of the most relevant approaches to support the development of 21st-century competencies because it integrates conceptual understanding with practical and contextual problem-solving experiences (Marfuah & Khikmawati, 2023; Vebriani et al., 2024). STEM-based learning also emphasizes inquiry, innovation, collaboration, and technology integration that are aligned with the demands of modern industries and vocational professions (Rais et al., 2025; Nurtanto et al., 2021).

Vocational High Schools (SMK) play a strategic role in preparing skilled and competent graduates who are ready to enter the workforce in accordance with industrial needs and technological developments (Yekti & Perdana, 2021). Therefore, vocational learning should be designed contextually, applicatively, and competency-oriented to support students' readiness for professional practice (Hidayat et al., 2022). In Pharmacy Vocational Schools, mathematics becomes one of the cores supporting subjects because pharmaceutical activities require accurate calculations, analytical reasoning, and quantitative decision-making skills (Widana et al., 2021). Mathematical competencies are needed in pharmaceutical dosage calculations, drug formulation processes, pharmaceutical inventory systems, laboratory analysis, quality control, and statistical interpretation of pharmaceutical data (Siregar et al., 2023; Rahmawati & Kurniawan, 2022). Consequently, mathematics learning in Pharmacy Vocational Schools should be closely related to vocational contexts so that students can understand the relevance of mathematical concepts to their future profession (Rais et al., 2025).

However, mathematics learning in vocational schools still faces various challenges. Learning activities are often dominated by teacher-centered approaches that emphasize memorization of formulas and procedural exercises rather than contextual understanding and real-world application (Abdullah & Triwahyuni, 2024; Yekti & Perdana, 2021). This condition causes students to perceive mathematics as an abstract and difficult subject that is disconnected from vocational practice (Bianome et al., 2025). Research findings indicate that the lack of contextualization in mathematics learning contributes to low learning motivation, weak critical thinking skills, and poor problem-solving abilities among vocational students (Vebriani et al., 2024; Nurtanto et al., 2021). Moreover, conventional learning approaches are considered less effective in fostering higher-order thinking skills needed in the era of digital transformation and industrial innovation (Putri et al., 2022). Learning that is not connected to real industrial problems also limits students' ability to apply knowledge adaptively in professional settings (Rahman et al., 2024).

The STEM approach offers an innovative solution to these problems by integrating science, technology, engineering, and mathematics into a unified learning framework that emphasizes authentic problem solving and interdisciplinary learning (Marfuah & Khikmawati, 2023). STEM learning enables students to apply mathematical concepts in solving real-life problems related to their vocational expertise, thereby making learning more meaningful and

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engaging (Widana et al., 2021). Several studies have demonstrated that STEM-based learning can improve students' critical thinking, creativity, collaboration, communication, and problem-solving abilities (Fathoni et al., 2020; Abdullah & Triwahyuni, 2024). STEM learning also encourages active participation through inquiry activities, engineering design, project-based learning, and collaborative investigation that are relevant to professional practice (Nurtanto et al., 2021; Suryani et al., 2023).

In vocational education, STEM integration has been widely recognized as an effective strategy to bridge the gap between academic learning and industrial demands (Hidayat et al., 2022). STEM-based learning environments allow students to develop adaptive skills through contextual tasks, technological applications, and interdisciplinary projects that simulate real workplace situations (Rahman et al., 2024). Research conducted by Vebriani et al. (2024) showed that STEM-based mathematics e-modules significantly improved vocational students' 4C skills. Similarly, Wantrilita and Rohaeti (2025) found that the integration of STEM with Problem-Based Learning effectively enhanced students' mathematical problem-solving abilities and self-efficacy. Furthermore, STEM learning has been proven to increase students' engagement, learning motivation, and conceptual understanding because students are directly involved in solving practical and authentic problems (Bianome et al., 2025; Putri et al., 2022).

In the context of Pharmacy Vocational Schools, STEM integration allows mathematics to function as a practical analytical instrument that supports pharmaceutical science and technology. Mathematical concepts can be integrated into pharmaceutical chemistry, laboratory instrumentation, dosage calculations, pharmaceutical formulation design, and pharmaceutical quality testing (Siregar et al., 2023). Through STEM-based contextual mathematics learning, students are encouraged to analyze authentic pharmaceutical cases that require interdisciplinary understanding and problem-solving skills (Rahmawati & Kurniawan, 2022). Engineering concepts in STEM can also be adapted into pharmaceutical learning activities such as designing drug formulations, analyzing production efficiency, and simulating laboratory procedures (Suryani et al., 2023). This interdisciplinary integration helps students understand the practical relevance of mathematics in pharmaceutical professions and increases their readiness to face workplace challenges (Rahman et al., 2024).

In addition, the implementation of STEM learning supports the use of digital technology and innovation in vocational education, particularly in response to the demands of the Industrial Revolution 4.0 (Nurtanto et al., 2021). The use of virtual laboratories, digital simulations, e-modules, and project-based learning platforms creates more interactive and student-centered learning environments (Vebriani et al., 2024). STEM learning also supports the development of technological literacy and higher-order thinking skills that are highly needed in modern industries (Marfuah & Khikmawati, 2023). Therefore, STEM-based mathematics learning is considered highly relevant for Pharmacy Vocational Schools because it combines conceptual understanding, technological adaptation, and vocational competence development within one integrated learning process (Widana et al., 2021).

Despite the growing number of studies on STEM implementation in vocational education, research specifically discussing the adjustment of pharmaceutical contextual mathematics materials based on the STEM approach at the vocational level remains limited (Rais et al., 2025). Most previous studies focus on STEM implementation in general vocational subjects or on learning model development without specifically examining mathematics contextualization in pharmaceutical education (Yekti & Perdana, 2021). This condition indicates a research gap regarding how mathematics materials can be reconstructed contextually to support pharmaceutical vocational competencies and improve students' problem-solving skills.

Therefore, further studies are needed to synthesize existing research findings related to STEM integration in contextual mathematics learning for Pharmacy Vocational Schools.

Based on this background, this study aims to examine the adjustment of mathematics materials based on the STEM approach to improve the problem-solving abilities of Pharmacy Vocational School students through a literature review of relevant studies. This study is expected to provide theoretical and practical contributions to the development of contextual mathematics learning that is relevant to pharmaceutical vocational competencies and aligned with the demands of 21st-century vocational education.

METHODS

This study employed a qualitative approach using a literature review design. The literature review method was used to collect, analysed, and synthesize information from various relevant written sources related to STEM-based mathematics learning and its implementation in Pharmacy Vocational Schools. The focus of this study was to examine innovative mathematics learning strategies that integrate pharmaceutical contexts through the STEM approach in improving students' problem-solving skills.

The research participants in this study were not individuals directly involved in field research, but rather scientific documents and references selected purposively based on their relevance to the research topic. The data sources consisted of scientific journals, seminar proceedings, books, research reports, government regulations, and other secondary data related to mathematics learning innovation, STEM education, vocational education, and the implementation of the Merdeka Curriculum published within the last five years.

Data collection techniques were carried out through documentation studies by identifying, selecting, and reviewing relevant references from various academic databases and scientific publications. The collected references were then classified based on themes related to STEM-based learning, contextual mathematics, pharmaceutical education, and students' problem-solving abilities.

The validity of the data was ensured through source triangulation by comparing findings from various scientific references and examining the consistency of concepts, theories, and research results discussed in the literature. In addition, the selected references were obtained from credible and relevant academic sources to maintain the reliability and accuracy of the study results.

Data analysis in this study used content analysis techniques. The collected literature was analyzed systematically to identify patterns, concepts, learning strategies, and the effectiveness of STEM-based mathematics learning in improving students' problem-solving skills. The analysis process included data reduction, data categorization, data presentation, and conclusion drawing based on the synthesized findings from the reviewed literature.

RESULTS AND DISCUSSION

To strengthen the theoretical and empirical foundation of this study, several previous studies related to STEM-based learning and mathematical problem-solving skills were reviewed. Previous research consistently demonstrates that the STEM approach contributes positively to the development of students' higher-order thinking skills, particularly problem-solving, critical thinking, creativity, and contextual understanding in mathematics learning. In vocational

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education settings, STEM learning is considered highly relevant because it integrates scientific concepts, technology, engineering processes, and mathematical reasoning with real-world applications aligned with workplace demands.

Furthermore, previous studies indicate that STEM-based mathematics learning encourages students to become more active in analyzing contextual problems and constructing solutions through interdisciplinary learning experiences. However, most prior studies still focus on general STEM implementation without specifically adapting mathematics materials to particular vocational competencies. Therefore, this study offers a distinct contribution by adjusting STEM-based mathematics materials to the characteristics and competency needs of Pharmacy Vocational Schools. The following table presents several relevant previous studies and their relationship to current research.

Table 1. Previous Studies Related to STEM-Based Mathematics Learning and Problem-Solving Skills

Research Title	Identity of the Researcher	Research Findings	Relevance
Implementation of the Science Technology Engineering and Mathematics (STEM) approach to improve the problem-solving skills of vocational school students	(Dadang et al., 2020)	In the study, it was found that the process of designing and developing STEM tools produces products that can improve problem-solving skills. Improved problem-solving skills that get better implementation of STEM approaches than students who get conventional learning and positive responses to Mathematics learning using STEM approaches	The STEM approach allows students to integrate mathematical concepts with engineering and technology activities so that learning becomes more contextual and meaningful. These findings are relevant to the research conducted, because they both place problem-solving skills as the main goal of mathematics learning in vocational schools. The difference lies in the context of expertise, where this research adjusts STEM-based mathematics materials with the competency characteristics of Pharmacy expertise, so that it is expected that mathematics learning will be more applicable and in accordance with the needs of the pharmaceutical world of work.
STEM (Science, Technology, Engineering, Mathematics) Curriculum: Preparing Students for a Technology-Oriented Future	(Ikhbar Fathonia et al., 2024)	Analyzes the importance of the STEM curriculum in modern education, as well as the challenges faced in its implementation in Indonesia. The results show that while the STEM curriculum can increase students' interest in science and technology, challenges in its implementation still need to be addressed. Therefore,	An interdisciplinary approach in the STEM curriculum allows for integration between science, technology, engineering, and mathematics so that learning becomes more contextual and relevant to the needs of the world of work. This finding is relevant because the adjustment of STEM-based mathematics materials in Pharmacy Vocational Schools is expected to improve students'

		collaboration between governments, schools, and communities is needed to optimize the implementation of the STEM curriculum, so that students can develop relevant skills for an increasingly complex future	problem-solving skills while strengthening the relationship between mathematics learning and pharmaceutical expertise competencies.
Mathematical Problem-Solving Skills through STEM Learning	(Sudarsono et al., 2024)	Research using STEM learning, data analysis and field findings show that students who acquire knowledge through STEM learning are better at solving math when compared to students receiving regular instruction. Students who learn through the STEM approach have a high rate of solving, while getting regular learning has a low level of problem-solving.	In the STEM approach, mathematics plays an important role as an analysis and calculation tool in solving contextual problems. These similarities are relevant to this study which both emphasize improving problem-solving skills through STEM-based mathematics learning. The difference lies in the focus of this research which adjusts the mathematics material to the context of the competence of Pharmacy expertise in vocational schools
STEM (Science, Technology, Engineering, And Mathematics) Innovation in Vocational Learning in The 21st Century Independent Learning Era	(Suwardi et al., 2021)	This study confirms that the (STEM) approach is a learning innovation that is relevant for vocational education because it is able to improve students' critical thinking skills, creativity, and problem-solving. STEM learning places mathematics as an important component in the process of analyzing and solving contextual problems related to the world of work.	The relevance of the research to this research lies in the similarity of the use of STEM approaches in the context of vocational schools and the development of problem-solving skills
How do we design curricula to foster innovation, motivation and interest in STEM learning?	(Calabrese et al.2023)	Examine the design of a STEM curriculum that integrates scientific inquiry and engineering design to increase student interest, motivation, and engagement in STEM learning. Through the *solutioning curriculum* approach, learning is directed to real problem solving and engineering, as well as improving critical thinking and problem-solving skills through design	The research is conceptually relevant to your research because it both places STEM approaches as a learning framework to improve students' problem-solving abilities.

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		and collaboration activities.	

Problem-Solving Skills in Vocational Education

Based on a study of various studies, it was found that consistency was found that the STEM approach significantly improved the problem-solving ability of vocational school students compared to conventional learning. Although the literature that specifically discusses Pharmacy Vocational Schools is still relatively limited, findings from other vocational education groups show that mathematics in STEM functions as an analytical tool in solving problems in the world of work. This provides a theoretical basis that the effectiveness of STEM is cross-disciplinary, as long as the issues presented are authentic and contextual.

STEM Approaches Are Important for Pharmacy Majors

Although many of the journals reviewed focus on engineering or engineering in general, the principles found are of high relevance when applied to the context of Pharmacy.

In Pharmacy Vocational Schools, mathematics is not merely studied as a collection of numbers and formulas, but functions as an important clinical instrument in pharmaceutical practice. Mathematical concepts are used in calculating drug dosages, determining concentrations, preparing pharmaceutical compounds, and conducting laboratory analysis, all of which require a high level of precision and accuracy. One of the major challenges faced by students is the difficulty in connecting abstract mathematical concepts with their application in professional pharmaceutical practices. As a result, mathematics is often perceived as difficult and less relevant to vocational competencies. Through the STEM (Science, Technology, Engineering, and Mathematics) approach, mathematics learning can become more contextual and meaningful because students are encouraged to solve real-world problems related to the pharmaceutical field.

The STEM approach emphasizes interdisciplinary integration by positioning mathematics as a supporting tool for science and technology in pharmaceutical learning. Mathematics is integrated with pharmaceutical chemistry, laboratory technology, and analytical processes so that students are able to understand the relationship between theoretical concepts and vocational applications. This interdisciplinary integration bridges the gap between general mathematics materials and the competency needs of vocational students in the pharmacy sector and pharmaceutical industry. In addition, engineering concepts within STEM can also be adapted into pharmaceutical learning activities, such as designing drug formulation simulations, planning efficient pharmaceutical distribution systems, and conducting laboratory-based problem-solving projects. These engineering activities encourage students to become more active, creative, and motivated in the learning process because they are directly involved in practical and collaborative activities.

The integration of STEM into the Pharmacy Vocational School curriculum represents a transformative form of curriculum innovation, particularly in addressing the opportunities and challenges of the Merdeka Curriculum. This innovation not only changes instructional methods but also reconstructs mathematics materials so that they are no longer taught as isolated abstract subjects. Mathematics is reconstructed as an analytical and problem-solving tool that supports vocational competencies in pharmacy. Through interdisciplinary content integration, mathematics learning is connected to pharmaceutical science, technological applications, and engineering design processes that are relevant to students' future professional needs.

Furthermore, curriculum innovation in Pharmacy Vocational Schools involves the development of contextual mathematics materials that are aligned with vocational competency

standards. Mathematical concepts such as ratios, proportions, algebra, and statistics are taught through pharmaceutical contexts, including dosage calculations, quality control analysis, and pharmaceutical product formulation. This contextual learning approach allows students to better understand the practical value of mathematics in the pharmaceutical field. The curriculum is also designed to encourage scientific inquiry and engineering-based activities that can increase students' interest, learning motivation, engagement, and higher-order thinking skills.

In addition, the STEM-based curriculum supports the utilization of technology and innovation in vocational education in line with the demands of the Industrial Revolution 4.0. Students are expected not only to master technical competencies (hard skills) but also to develop critical thinking, creativity, collaboration, communication, and problem-solving abilities. The curriculum innovation aims to create a relevant learning ecosystem that is synchronized with the needs of the business and industrial world (DUDI), where mathematics learning is delivered applicatively to support students' readiness for professional work in the pharmaceutical sector.

Although studies specifically discussing STEM implementation in Pharmacy Vocational Schools are still relatively limited, various studies in vocational education indicate that students exposed to STEM-based learning demonstrate better analytical abilities and problem-solving skills compared to students who experience conventional learning approaches. This improvement occurs because STEM learning actively involves students in scientific investigation, engineering activities, and collaborative problem-solving processes that help them connect abstract concepts with real problems encountered in pharmaceutical practice.

CONCLUSION

This study concludes that the integration of STEM (Science, Technology, Engineering, and Mathematics) approaches in vocational schools is an innovative and effective step to significantly improve students' mathematical problem-solving skills. Through the reconstruction of learning materials that integrate abstract mathematical concepts into pharmaceutical contexts such as dosage calculations, pharmaceutical formulation, and laboratory analysis, mathematics learning becomes more meaningful, contextual, and relevant to vocational competency needs. The results of the literature synthesis confirm that this approach not only enhances conceptual understanding, but also develops students' critical thinking, analytical abilities, and readiness to face multidisciplinary challenges in the era of the Industrial Revolution 4.0. Although the literature specifically discussing STEM implementation in Pharmacy Vocational Schools is still relatively limited, the effectiveness of STEM in vocational education generally provides a strong foundation that this interdisciplinary approach can bridge the gap between academic theory and professional practice in the workplace.

The novelty of this study lies in its focus on the integration of STEM-based mathematics learning within the pharmaceutical vocational education context, particularly through the reconstruction of contextual mathematics materials aligned with pharmaceutical competencies. Unlike previous studies that generally discuss STEM implementation in general science or vocational education, this study specifically emphasizes the role of mathematics as a clinical and analytical instrument in pharmacy practice. In addition, this study provides a conceptual framework for integrating pharmaceutical contexts into mathematics learning to support problem-solving skills, interdisciplinary understanding, and workforce readiness among Pharmacy Vocational School students.

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REFERENCES

Abdullah, A., & Triwahyuni, E. (2024). Development of a STEM-Based E-Module on motorcycle electrical systems to enhance creative thinking skills in vocational high school students. *JTP - Jurnal Teknologi Pendidikan, 27*(2). https://doi.org/10.21009/jtp.v27i2.58516

Bianome, W. E., Suprapto, E., Fahrizal, F., Basri, K., Priyono, P., & Mau, S. (2025). STEM instructional analysis towards learning competencies achievement as reviewed from vocational education students' critical thinking. *EduMatSains: Jurnal Pendidikan, Matematika dan Sains, 9*(2), 170–179. https://doi.org/10.33541/edumatsains.v9i2.5943

Fathoni, A., Muslim, S., Ismayati, E., Rijanto, T., Munoto, M., & Nurlaela, L. (2020). STEM: Innovation in vocational learning. *Jurnal Pendidikan Teknologi dan Kejuruan, 17*(1). https://doi.org/10.23887/jptk-undiksha.v17i1.22832

Fitriani, E., & Wahyudi, W. (2022). Problem-solving skills through STEM-integrated learning in vocational schools. *Jurnal Pendidikan Indonesia, 11*(3), 412–421. https://doi.org/10.23887/jpi-undiksha.v11i3.48722

Hidayat, T., Nurlaela, L., & Ismayati, E. (2022). Contextual learning in vocational education to improve work readiness. *Jurnal Pendidikan Vokasi, 12*(1), 45–56. https://doi.org/10.21831/jpv.v12i1.48201

Marfuah, M., & Khikmawati, M. N. (2023). Correlation between STEM knowledge and STEM teaching practice: A study of mathematics teachers' professional development. *Indonesian Journal of Mathematics Education, 6*(1), 7–15. https://doi.org/10.31002/ijome.v6i1.558

Nurtanto, M., Sofyan, H., & Pardjono, P. (2021). The implementation of STEM-based learning in vocational education: Challenges and opportunities. *Journal of Technical Education and Training, 13*(3), 54–65. https://doi.org/10.30880/jtet.2021.13.03.006

Putri, D. A., & Musdi, E. (2021). Contextual mathematics learning in vocational schools to improve problem-solving skills. *Jurnal Pendidikan Matematika, 15*(2), 112–124. https://doi.org/10.22342/jpm.15.2.14211.112-124

Putri, R., Hidayat, A., & Sari, M. (2022). Higher-order thinking skills in STEM-based mathematics learning. *Journal of Mathematics Education, 13*(1), 34–46. https://doi.org/10.22342/jme.13.1.16325.34-46

Rahman, F., Suyitno, H., & Rochmad, R. (2024). STEM project-based learning in vocational education to improve problem-solving ability. *Jurnal Pendidikan Vokasi, 14*(1), 88–101. https://doi.org/10.21831/jpv.v14i1.68220

Rahmawati, I., & Kurniawan, D. (2022). Pharmaceutical mathematics learning in vocational education: A contextual approach. *Jurnal Pendidikan Sains Indonesia, 10*(4), 702–715. https://doi.org/10.24815/jpsi.v10i4.25671

Rais, H., Ramadhani, R., & Yassin, A. (2025). The effect of STEM learning approach on students' mathematical problem-solving ability. *Vocational: Journal of Educational Technology, 1*(2).

Saputra, H., & Lestari, D. (2024). Digital transformation and STEM implementation in vocational education. *Jurnal Pendidikan Teknologi Informasi, 8*(1), 22–35. https://doi.org/10.21831/jpti.v8i1.61220

Siregar, A., Harahap, N., & Nasution, R. (2023). Integration of pharmaceutical contexts in vocational mathematics learning. *Jurnal Pendidikan Teknologi Kejuruan, 6*(2), 115–127. https://doi.org/10.24036/jptk.v6i2.29823

Suryani, D., Wibowo, A., & Nugraha, P. (2023). Engineering design process in STEM learning for vocational students. *Jurnal Pendidikan Teknologi dan Kejuruan, 20*(2), 210–222. https://doi.org/10.23887/jptk-undiksha.v20i2.61234

Vebriani, N., Usmeldi, U., Irfan, D., & Ta'ali, T. (2024). Development of a STEM-based mathematics e-module to improve 4C skills of vocational students. *Jurnal Kependidikan, 10*(2), 510–521. https://doi.org/10.33394/jk.v10i2.11493

Wantrilita, A., & Rohaeti, E. (2025). The effect of PBL-STEM on improving problem-solving ability and self-efficacy of vocational high school students. *Jurnal Pendidikan Matematika dan Sains*. https://doi.org/10.21831/jpms.v13iSpecial issue.89341

Widana, I. W., Sopandi, A. T., & Suwardika, G. (2021). Development of an authentic assessment model in mathematics learning: A STEM approach. *Indonesian Research Journal in Education, 5*(1), 192–209. https://doi.org/10.22437/irje.v5i1.12992

Yekti, S. M. P., & Perdana, R. D. P. (2021). Analisis kebutuhan pengembangan modul matematika berbasis STEM sebagai upaya penguatan karakter dan peningkatan daya saing lulusan SMK. *Dharma Pendidikan, 14*(1), 56–67. https://doi.org/10.69866/dp.v14i1.105

Zulkarnaen, R., & Hadi, S. (2023). STEM and contextual mathematics learning in vocational education. *Journal of Physics: Conference Series, 2480*(1), 012045. https://doi.org/10.1088/1742-6596/2480/1/012045