Jurnal Karya Abdi Masyarakat
Volume 9, No. 1, 2025, pp. 15 – 26
https://doi.org/10.22437/jkam.v9i1.42481

OPEN ACCESS

Improving Teachers' STEM Competence: Impact of A Collaborative Professional Development Workshop

Rooselyna Ekawati[1]*, Sifak Indana[2], Wasis[3], Rudianto Artiono[4], Dian Novita[5], Guntur Trimulyono[6], Muhamad Arif Mahdiannur[7]

[1, 2, 3, 4, 5, 6, 7]Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya, Indonesia
*Email: rooselynaekawari@unesa.ac.id

Article Info
Received: 14/03/2025
Revised: 15/04/2025
Accepted: 18/04/2025

Abstract
The Science, Technology, Engineering, and Mathematics (STEM) approach to learning plays an important role in improving teacher competency, learning innovation, and technology use skills. However, the results of an initial survey at Sekolah Indonesia Makkah showed that 44.12% of teachers faced challenges in the form of a lack of training and understanding related to STEM integration. This study involved 34 teachers and aimed to improve their ability to implement STEM-based learning through the Collaborative Professional Development (CPD) approach. The results showed that teachers who participated in CPD activities experienced a significant increase in their understanding and readiness to implement STEM. In addition, teachers began to realize the benefits of STEM learning in developing students' affective, cognitive, and psychomotor aspects, as well as its potential as a means of career guidance. As many as 52.94% of teachers stated that they strongly believed that STEM was important to implement, and 58.82% considered the CPD program to be continued. This study recommends that CPD training be carried out continuously with more applicable and contextual materials. Strengthening collaboration between teachers and the integration of STEM-based curriculum is also needed to support the sustainability and effectiveness of the program in the long term.

Keywords: Collaborative Professional Development, Contextual Curriculum, Innovative Learning, STEM, Teacher

How to Cite: Ekawati, R., Indana, S., Wasis, W., Artiono, R., Novita, D., Trimulyono, G., & Mahdiannur, M. A. (2025). Improving teachers' STEM competence: Impact of a collaborative professional development workshop. *Jurnal Karya Abdi Masyarakat, 9*(1), 15-26. https://doi.org/10.22437/jkam.v9i1.42481

INTRODUCTION

Entering the 21st century, the application of technology in education continues to grow, including integrating technology into the learning curriculum in recent years (Isti'ana, 2024). One innovative technology-based approach is STEM learning, which includes collaboration between science, technology, engineering, and mathematics disciplines. Integrated STEM makes students problem solvers, inventors, and innovators, builds independence, think logically, are technologically literate, and can connect STEM education with the world of work (Karmiati et al.,

2024). In implementing STEM learning, teachers are one of the main components who have a strategic role in supporting higher education in facing the era of digitalization and the Industrial Revolution 4.0. This aligns with Yoshida and Sølberg (2024), who state that STEM education is essential for building a better future, and teachers have a crucial role in attracting students to STEM. Therefore, teachers must have strong core competencies and be able to design learning activities per the Industrial Revolution 4.0. This is because the quality of teachers must match the performance of teachers needed in the industrial era 4.0 (Maddukeleng et al., 2023). Teachers with high technological competence can provide more effective teaching and encourage student interest in this field. Research results from Nurhidayat et al. (2024) show that technology integration and teacher competency significantly influence the development of 21st-century learning. So, teachers need to use technology effectively to improve learning. By integrating technology into the classroom, teachers can create engaging and interactive learning experiences (Azennoud, 2022).

The implementation of this mentoring was carried out at the Indonesian School of Mecca, Saudi Arabia, which has unique geographical conditions such as a prolonged dry season so that the temperature on earth increases and other phenomena that can arise (Printina, 2019). The uniqueness of geography, culture and the dynamics of local community life are different contextual sources compared to other countries. Through the surrounding phenomena, it can be used as problem-based learning material with STEM which emphasizes the integration of STEM (Chia et al., 2023). However, the teachers at the school face several challenges including limited access to professional training, difficulty in adapting to rapid technological developments, and the need to integrate technology into the curriculum used. The education system in Saudi Arabia emphasizes the integration of educational values including ethics, religiosity and Islamic art and Arabic literature (Rosita et al., 2024.). These characteristics reflect the importance of education that not only emphasizes cognitive aspects but also strengthens local moral and cultural values. In the context of the Indonesian School of Mecca, the Saudi Arabian education system is an environment that also influences the learning approach taken by teachers. Therefore, in developing STEM learning, teachers are not only required to master aspects of science and technology but must also be able to adapt to the learning so that it remains in line with educational values that apply contextually. This is the basis for the importance of teacher development so that they can integrate the STEM approach with the characteristics of the applicable curriculum.

CPD workshop is a form of training or professional development that involves active collaboration between facilitators and participants with the main goal of improving knowledge, skills, and professional practices through a participatory approach (Wood et al, 2017). In a workshop that emphasizes active and collaborative training participants, participants not only receive material passively, but also engage in discussions, interactive activities and reflections together in a dynamic, relevant and sustainable learning environment (Defianty et al., 2024). The results of a systematic review of teacher professional development programs reveal that the success of the program is highly dependent on the performance of teachers and the teacher's experience of learning after some time of mentoring (Robetson et al., 2018). This training is collaborative, unlike conventional training which tends to be one-way. This mentoring emphasizes the importance of active teacher involvement in the training process through discussion, co-design, and reflection on STEM learning practices. This training also presents an empirical

evaluation of the direct impact in terms of content knowledge, pedagogy, and teacher confidence in implementing STEM learning. Based on this background, the research team felt the need to conduct and organize teacher training and mentoring at the Indonesian School of Makkah. Other studies have shown that higher levels of STEM training can increase teacher confidence in implementing STEM learning (Buechel et al., 2024). The results of the initial survey showed that 44.12% of teachers still face obstacles in understanding the concept and how to integrate STEM concepts without leaving the characteristics of the country's typical curriculum. Training with a CPD Workshop approach that was designed collaboratively and aims to improve teacher competence in planning and implementing STEM learning. This mentoring also considers the uniqueness of the curriculum in Saudi Arabia which emphasizes unique natural phenomena and religious values, so that STEM learning becomes more relevant.

METHODS

Subject and Time of Research

This research is experimental research, starting by identifying the characteristics of the research subjects by distributing response questionnaires. The research period was carried out from August to November. The subjects of this research were 34 teachers at the Makkah Indonesian School, Saudi Arabia, with the characteristics of the participants as in Table 1. Participants will be guided to create STEM-based learning tools (grouped into groups of 4-6 people). Grouping is based on suitability to the subjects taught by the teacher.

Table 1. Demographic Characteristics of Participants

Demographic characteristics of participants		f
Field	Arabic / Islamic religious education	11
	Science	4
	Math	6
	Language	7
	Arts	2
	Social	4
Length of Teaching: 11-20 years	Hearing the concept of STEM clearly before joining the program	24
	Implementing STEM education in Fielding	10
Length of Teaching: 5-10 years	Hearing the concept of STEM clearly before joining the program	28
	Implementing STEM education in Fielding	6

Procedure

The workshop used a CPD Workshop approach (Sonsupap et al., 2024). This training is conducted online and offline. Next, a survey was taken in the form of open questions to assess the workshop participants' views about STEM and how to apply it before and after the mentoring implementation. An increase in the ability to implement STEM learning can be seen from an increase in understanding of the implementation of STEM in learning and readiness to apply STEM learning, which is indicated by the ability to conclude the importance of applying STEM for students in terms of improving affective aspects, increasing cognitive, increasing psychomotor, and how STEM has an effect as a guidance facility. Students' careers. The implementation of the workshop is based on Figure 1.

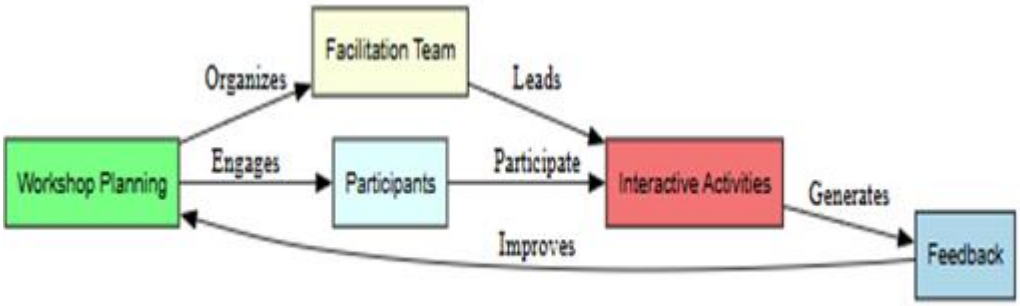

Figure 1. Collaborative Professional Development Workshop

Figure 1 depicts CPD workshop conducted by team. The process begins with workshop planning involving a team of facilitators and participants. The team of facilitators leads interactive activities that encourage active participation. The team of facilitators consists of experts in innovative learning and technology-based learning media development. This activity produces feedback that is used to improve future planning. This flow emphasizes the importance of collaboration, participation and ongoing program evaluation in improving teacher competency.

Data Collection and Data Analysis

The research data obtained were analyzed using descriptive quantitative methods by measuring the improvement in teacher competence. This improvement was assessed by comparing the number of correct answers given before and after the implementation of the activity. Each response was converted into a percentage to identify trends, which were then described using a Likert scale as presented in Table 2.

Table 2. Criteria Scale for Measuring the Improvement in Teacher Competence

Category	Percentage (%)	Interpretation
Very Important	61-100	Very positive perception of the importance of STEM
Important	41-60	Positive perception of the importance of STEM
Quite Important	21-40	Fair perception of STEM
Less Important/ Not Important	0-20	Low or unimportant perception of STEM

Table 2 is used to ensure that the training not only improves perceptions, but also teachers' factual and conceptual abilities related to STEM learning.

RESULTS AND DISCUSSION

Workshop Planning

Table 1 shows the diversity of teacher characteristics found in schools. The material is adjusted to the skills and practical strategies in integrating STEM in their teaching fields (Arabic, Islamic Religious Education, Science, Mathematics, Language, Arts, and Social Studies). Session 1: Introduction to the concept of STEM, Session 2:

STEM teaching strategies in education. Session 3: Practice of developing teaching modules and implementing STEM; Session 4: Challenges and Solutions in Implementing STEM. The number of participants who have heard the word STEM is very high, but teachers who have heard the concept of STEM can still apply it in the classroom. The core of this workshop is to place a place that emphasizes interactive activities. This activity is carried out with online and offline assistance. Online implementation is carried out through the WA group for initial coordination of implementation for offline implementation carried out at the Indonesian school of Mecca. As shown in Figure 2.

Figure 2. Offline Workshop Implementation at the Indonesian School of Mecca

The implementation of the CPD workshop is designed in a blended manner, namely combining online and offline meetings to accommodate the needs of participants while considering the limited distance and time. Offline activities such as those in the picture are carried out in the middle of the activity with the aim of providing a basic understanding of STEM concepts, delivering this material, and facilitating group discussions and collaborative STEM learning design. This stage is important for building a strong conceptual understanding and forming connections between participants directly.

Facilitation Team

The existence of diversity in terms of age, teaching time makes the role of the facilitator can be summarized into 2 main functions, namely compiling and delivering material according to needs and facilitating small group discussions. The existence of small discussion facilities with existing diversity will create an inclusive learning environment, workshop participants can share experiences and learn from each other (Rahmawati et al, 2024). Small group discussions resulted in increased involvement in completing and contributing ideas. In this method, the facilitator acts as a companion, not just as a facilitator, but also as a driver so that participants can find solutions together through interaction and collaboration. In small groups, workshop participants felt more comfortable in speaking compared to large discussions, feeling awkward or afraid of criticism was reduced so that participants were more confident in conveying their ideas. There is a more focused discussion so that workshop participants can explore the topic in more depth, discuss various perspectives and analyze the situation more critically (Andayani et al., 2022). The facilitator team is divided into two teams with a focus on innovative STEM-based learning topics and facilitators who are experts in developing learning media.

Participants

The results of identifying participant characteristics show that those with teaching experience of 11-20 years and those with teaching experience of 5-10 years understand the meaning of STEM learning but have not applied it. This is proven by the initial data collection related to challenges in STEM learning, obtaining data as in the Table 3.

Table 3. Survey of STEM Learning Challenges

Question	People	Presents
Limited resources (tools, materials, etc.)	10	29,41%
Lack of training/understanding	15	44,12%
Limited time to develop material	9	26,47%

The results of the presentation are presented in Table 3 as the basis for the workshop team in designing and delivering training materials. Teachers with 5-20 years of experience generally understand the concept of STEM learning but have not implemented it. In line with the initial data that has been mentioned in the background of this training, namely the lack of related training after the identification results were carried out, another factor was found, namely limited resources and time for developing technology-based materials.

Interactive Activities

This interactive activity is the core activity, and it shows collaboration in each group to complete several stages contained in the e-worksheet provided (Ahadi et al., 2024). Interactive activities consist of Hands-on Activities, completing the challenges in the worksheet, and compiling STEM-based modules that will be applied in the classroom. Additional media, such as e-worksheets, can help teachers identify what needs to be prepared in implementing STEM learning (Muhammad et al., 2024). Based on the results of observations and discussions during the workshop, you can find out the extent to which teachers understand STEM concepts as in Table 4 and they are ready to apply it so that they can conclude the extent to which STEM will contribute to students as shown in Table 4.

Table 4. Teachers' Perspectives on STEM Learning

Question	R	% before	%after
Is the following statement about STEM true? The integration of natural science, technology, engineering, and mathematics in learning points is related to each other	Correct	76,47	97,06
	False	23,53	0
	No responses	0	2,94
The following is one of the characteristics of STEM. Students work collaboratively in solving real problems.	Correct	29,42	76,47
	False	52,94	23,53
	No responses	17,65	0
STEM integrates science, technology, engineering, and mathematics collaboratively and can be applied at all levels of elementary, middle, and high school education	Correct	26,47	88,23
	False	58,82	11,76
	No responses	14,70	0

Table 4 shows the results of observations and discussions during the activity; the increase in teachers' understanding of the STEM concept was significant. The contest on understanding the integration of science, technology, engineering and mathematics increased from 76.47% to 97.06%. Collaborative understanding of STEM increased from 29.42% to 76.47% and the discussion that STEM can be applied at all levels of education increased from 26.47% to 88.23%. These results indicate that the workshop activities and the use of e-worksheet assistance provided contributed positively to increasing teachers' understanding and readiness to apply the STEM approach to the teaching and learning process. In addition to measuring teachers' cognitive understanding of the STEM concept, evaluations were also conducted to determine the extent to which teachers understand the role of STEM learning in student development.

Table 5. The Role of STEM Learning in Students' Development

Topic	Questions	Responses	% before	% after
Increased affective aspects	STEM can increase learning success. Attract interest and motivation to learn.	Disagree Neutral Agree	88,23 11,76 0	11,76 58,82 29,41
Cognitive Enhancement	STEM can develop problem-solving thinking skills	Disagree Neutral Agre	100 0 0	11,76 29,41 58,82
Psychomotor Improvement	STEM Develop skills by increasing the use of technology	Disagree Neutral Agree	58,82 11,76 29,41	0 11,76 88,23
Career guidance (contribution to the future)	STEM Contributes to the choice of profession, develop engineering skills, Ensures the growth of specialists in the field	Disagree Neutral Agree	85,29 2,94 11,76	14,70 79,41 5,88

Table 5 shows a recapitulation of the results of teacher perceptions before and after the training. Before the training, many teachers had not seen the role of STEM in depth in increasing students' interest in learning (88.23% disagreed). However, after the training, there was a positive change with 29.41% agreeing. The biggest reason given was that when students are accustomed to using technology, they are afraid of being addicted to using technology which can later lead students astray. After this training, teachers began to understand the concept of technology that must be provided and how to develop technology in learning. Significant changes also occurred after the psychomotor aspect from 29.41% to 88.23%. In general, this training showed significant gains in increasing understanding of STEM integration in learning towards students' cognitive and psychomotor aspects. When a teacher understands the benefits of STEM, it increases the teacher's motivation to apply it in learning (Setari et al, 2024). As material for the final evaluation of the activity, teachers were also asked to provide an assessment of how important STEM learning is, such as in Table 6.

Table 6. The importance of STEM in Learning

Category	Amount	Presentation
Very important	18	52,94%
Important	14	41,18%
Quite important	2	5,88%

Table 6 shows that most respondents said that STEM is very important with 52.94%, stating important with 41.18% and only 5.88% considered STEM quite important. These data show that after the training, many teachers realized the urgency and relevance of implementing STEM learning as an approach that can improve the quality of learning and prepare students to face future challenges. Teachers' belief in the benefits of STEM shows that they are more prepared and motivated to apply STEM approaches in the learning process (Yuliardi e al., 2023; Happy et al., 2024).

The results of data analysis showing an increase in the score of positive answers is shown by the frequency of answers being sure-very sure being more significant than the answers not being sure. Apart from the quantitative data provided, discussions in each group showed very positive changes in how teachers saw the application of STEM in the classroom. (Note: A= Researcher, B= Teacher)

A : *How much more confident do you feel to try STEM in learning after this training? To what extent do you agree that the explanations from the facilitator and the results of the discussions during the training opened your insight into STEM learning that can be applied in all subjects?*

B : *I feel more confident about trying project-based methods and using technology in my lessons. The explanation from the facilitator and the results of the joint discussion opened my horizons; it turns out that STEM is not only for science and mathematics but can be applied in all subjects*."

Feedback

The feedback process is carried out to help facilitators and organizers measure the effectiveness and teaching methods used so that they can provide a basis for continuous improvement and development. At this stage, the facilitator can confirm that the STEM workshop has a positive impact on increasing teacher competency. Based on the discussion results, the workshop participants gave a positive role as shown in the transcript below.

A : *To what extent do you feel this activity helps you with STEM learning?*

B : *Previously, I would like to thank the presenters for this activity to understand a little about STEM. Providing examples of teaching modules to teachers regarding the implementation of STEM learning and accompanying implementation in class is very clear. Hopefully, in the future, there will be training related to STEM. Once again, Thank you.*

The results of the feedback regarding program sustainability are shown in Table 7.

Table 7. Results of Program Sustainability Responses

Category	Likert Scale	Amount	Presentation
Unnecessary	1	0	0%
Simply Necessary	3	5	14,71%
Necessary	4	9	26,47%
Very Necessary	5	20	58,82%

Table 7 shows data on participants' perceptions of the sustainability of the training program. The results show that many teachers felt the benefits of the training and wanted the program to continue, both in the form of further training and assistance in implementing STEM in schools. STEM learning is important to instill in students because it has a perfect role in preparing them to face challenges in an era of increasingly developing technology (Winda et al., 2024). STEM learning focuses on mastery of theory and applying knowledge in real life, developing critical thinking skills, problem-solving, creativity, and innovation (Fauziah et al., 2024). This is expected to form a generation that is better prepared to face the challenges of the world of work, which increasingly requires competence in the field of STEM (Fajria et al., 2022). To overcome problems with STEM implementation, assistance is provided to teachers through CPD Workshops. This approach was chosen because it can encourage active interaction between teachers and facilitators through collaborative activities that allow teachers to share experiences, learn together, and solve problems collectively (Duisenbayev et al., 2024). This stage in CPD prioritizes interactive activities to improve teacher understanding and practical skills. During the workshop, the team prepared worksheets to guide teacher activities. The worksheets presented contain material based on environmental problems, and the teacher is facilitated to discuss how to solve these problems. After that, they design STEM-based learning with the group and the facilitator's assistance.

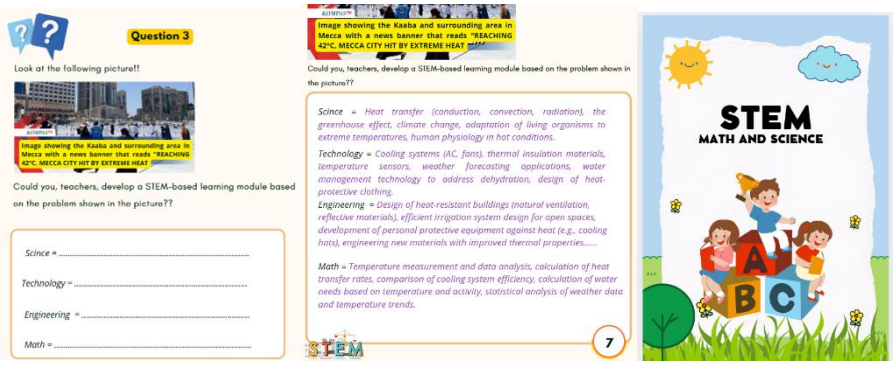

Figure 3. Problem-based worksheet and teacher answers

The implementation of CPD-based training in Indonesian schools in Mecca not only aims to improve teachers' understanding of STEM but also to foster their readiness to integrate technology-based learning. The use of environmental issues in Mecca that are identical to conditions in Mecca as shown in Figure 3 as the context of teaching materials in the worksheet has proven to be meaningful, so that teachers can relate STEM concepts

to students' real lives. Activities with sufficient training frequency will provide more in-depth guidance regarding STEM curriculum development in the classroom (Kolesynk et al., 2024). This training activity also has limitations that need to be considered for future development. One of the limitations is the distance of the location which is quite far and the limited time for mentoring. In addition, the variation in the level of teachers' understanding of technology and the STEM approach is also a challenge, especially in integrating local values and the Saudi Arabian curriculum into STEM practices. Strengthening the learning community between teachers also needs to be developed to create a professional network that supports the exchange of ideas and good practices in contextual and sustainable STEM learning.

CONCLUSION

Teachers who are involved in self-development through CPD workshops increase their understanding of the implementation of STEM in learning, as shown by an increase in correct answers to comprehension test questions and teachers' increased readiness to apply STEM learning, seen by being able to conclude the importance of applying STEM for students in terms of increasing affective aspects. Cognitive improvement, psychomotor improvement, and STEM influence are career guidance facilities for students with sure-very-sure answers. The survey results show that 52.94% of teachers firmly believe that STEM is necessary to apply in education. For the program's sustainability, 58.82% of participants stated that this program needs to be continued. Time constraints, distance and diverse teacher backgrounds are challenges in deepening the material and its implementation. Further activities are planned to include further mentoring, the formation of a community of practitioners and the preparation of contextual STEM learning guides according to the subject teachers' fields.

ACKNOWLEDGMENTS

I would like to thank you for funding this research. This research was funded by the Research and Community Service Unit of Universitas Negeri Surabaya with contract number 031-99425414.

DECRALATIONS

Author Contribution	:	RE: Conceptualization, Writing - Original Draft, Editing and Visualization; SI: Writing - Review & Editing, Formal analysis, and Methodology; W: Validation and Supervision; RA: Writing - Review & Editing, Formal analysis, and Methodology; DN: Validation and Supervision; GT: Writing - Review & Editing, Formal analysis, and Methodology; MAM: Conceptualization, Writing - Original Draft, Editing and Visualization;
Funding Statement	:	This research was funded by the Research and Community Service Unit of Universitas Negeri Surabaya with contract number 031-99425414.
Conflict of Interest	:	The authors declare no conflict of interest.

Additional Information : Additional information is available for this paper.

REFERENCES

Ahadi, A., Bower, M., Lai, J., & Singh, A. (2024). Evaluation of teacher professional learning workshops on the use of technology - a systematic review. *Professional Development in Education*, *50*(1), 221–237. https://doi.org/10.1080/19415257.2021.2011773

Andayani, E., Mustikowati, I., Setiyowati, W., & Firdaus. (2022). Case Method: optimizing critical thinking, creativity communication skills and collaboratively of students according to MBKM in the 21st century era. *Journal of Social Studies Research and Education (JPPI), 16*(1), 52-60. https://doi.org/10.21067/jppi.v16i1.6973

Azennoud, Z. (2022). Technology literacy as a post-COVID-19 survival competence in higher education: A narrative analysis of students' experiences and prospects. *International Journal of Didactical Studies*, *3*(2), 1-9. https://doi.org/10.33902/IJODS.202212968

Buechel, C., Dougherty, K., Carter, V., & Topalcengiz. (2024). Elementary teachers' self-efficacy and its role in STEM implementation. *Turkish Journal of Education*, *13*(3), 217-238. https://doi.org/10.19128/turje.1267839

Chia, L., & Maat, M. (2023). STEM Integration in Mathematics Learning and Facilitation (PDPC): A Systematic Literature Review. *Journal of World Education, 5*(3), 161-177. https://doi.org/10.55057/jdpd.2023.5.3.13

Defianty, M., & Wilson, K. (2024). Using collaborative action research to promote criticalthinking pedagogies in ELT in Indonesia. *Journal of Teacher Education, 52*(5), 607-621. https://doi.org/10.1080/1359866X.2024.2410837

Duisenbayev, A., Shavaliyeva, Z., Khassanova, I., Turebayeva, S., & Medeubayeva, K. (2024). The study of effective methods and strategies for the professional development of educators: mentorship, collaboration, and self-organization skills. *International Journal of Education in Mathematics, Science and Technology, 12*(2), 450-469. https://doi.org/10.46328/ijemst.4014

Fajria, R., Yerizon., Musdi, E., & Permana, D. (2022). Development of mathematics learning tools using the project-based learning model integrated with STEM to improve the creative thinking skills of class VIII junior high school student. *JEMS Journal of Mathematics and Science Education, 10*(1), 92-102. https://doi.org/10.25273/jems.v10i1.11918

Fauziah, A., & Wijayanti. (2024). Application of e-module assisted stem learning model to problem solving. *Journal of Mathematics Education, 8*(2), 1453-1462. https://doi.org/10.31004/cendekia.v8i2.3225

Happy, N., Prayito, M., Ariyanto, L., Safitri, D., & Sari, P. (2024). PKM STEM-AR education for mathematics teachers in Batang district. *Community Development Journal, 5*(6), 10976-10983. https://doi.org/10.31004/cdj.v5i6.37303

Isti'ana, A. (2024). Integration of technology in islamic education learning. *Indonesian Research Journal on Education, 4*(1), 302–310. https://doi.org/10.31004/irje.v4i1.493

Karmiati, W., Herman., & Mardiana, A. (2021). Building STEAM foundation through play activities at TK Negeri 02. Mekar Sari. Kab, Boalemo Gorontalo. *Journal of Thought and Learning Development, 3*(4), 127-132. http://www.ejournal-jp3.com/index.php/Pendidikan/article/view/192

Kolesynk, L., & Biseth, H. (2024). Professional development in teacher education through international collaboration: when education reform hits Ukraine. *Professional Development in Education, 50*(2), 347-359. https://doi.org/10.1080/19415257.2023.2193197

Maddukelleng, Jihan, G., & Murcahyanto. (2023). Hybrid learning innovation: challenges for developing teachers' skills in indonesia. *Journal of Religious and Social Sciences, 17*(2), 842-854. http://dx.doi.org/10.35931/aq.v17i2.1959

Muhammad, N., & Widowati, A. (2024). Improving students' problemsolving skills through STEM PJBL learning of peat propagation material. *Pancasakti Science Education Journal, 9*(1), 9-19. https://doi.org/10.24905/psej.v9i1.202

Nurhidayat, E., Mujiyanto, J., Yuliasri, I., & Hartono, R. (2024). Technology integration and teachers' competency in developing 21st-century learning in EFL classroom. *Journal of Education and Learning (EduLearn), 18*(2), 342-349. https://doi.org/10.11591/edulearn.v18i2.21069

Printina, I. (2019). Analysis of the geographical potential of the Middle East into digital comics based on a pedagogical paradigm. *Reflektif. Jurnal Agastya, 9*(1), 44-56.

Rahmawati, S., & Nadzari, A. (2024). Innovation of islamic religious education teachers in implementing the independent curriculum at Citra Madinatul Ilmi Plus High School, Banjarbaru. *ADDABANA: Journal of Islamic Religious Education, 7*(1), 27-46. https://doi.org/10.47732/adb.v7i1.308

Robetson, A., Curtis, M., & Dann. (2018). Outcomes of a collaborative contextualised learning approach to teacher professional development in Papua, Indonesia. *The International Education Journal: Comparative Perspectives, 17*(2), 88-101. https://eric.ed.gov/?id=EJ1184048

Rosita, N., & Khojir. (2024). Strengthening the islamic education system in Saudi Arabia: analysis of literature review and best practices. *Borneo Tarbiah and Teacher Training Journal, 5*(3), 313-328. https://doi.org/10.21093/jtikborneo.v5i3.8575

Setari, D., Yuliawati, L., & Mardjohan. Implementation of projectbased learning (PJBL) learning model based on STEM approach to improve mathematical creative thinking skills. *Mathematics Education Journal April Eleven, 3*(1), 82-94.

Sonsupap, K., & Cojorn, K. (2024). Collaborative professional development impacts teachers' ability to foster higher-order thinking. *Journal of Education and Learning (EduLearn), 18*(2), 561-569. https://doi.org/10.11591/edulearn.v18i2.21182

Winda, H., Paramita, I., Nurjannah., & Ratnaningtiyas. (2024). Application of the stem approach to students' psychomotor abilities in science learning. *Journal of Science Education, 1*(2), 38-47. https://doi.org/10.29408/hijase.v1i2.2739

Wood, K., Jaidin, H., Jawawi, R., & Salleh, S. (2017). How and what teachers learn from collaborative professional development. *International Journal for Lesson and Learning Studies, 6*(2), 151-168. https://doi.org/10.1108/IJLLS-09-2016-0028

Yoshida, M., & Selberg, J. (2024). Science teachers' beliefs on science teaching and learning for implementing in STEM education. *Science Education International, 35*(3), 192-197. https://doi.org/10.33828/sei.v35.i3.2

Yuliardi, R., Firmasari, S., Kusumah, S., Nurhanag., & Maizora. (2023). Implementation of innovative learning based on STEM and digital learning to improve the quality of learning for elementary school teachers in Cipondok Village, Kuningan Regency. *Indonesian Community Service Journal (JAMSI), 3*(2), 499-508. https://doi.org/10.54082/jamsi.673