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Improving the Competency of Junior High School Teachers Through Training and Mentoring in STEM-Based PBL Model

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Abstract

A deficit in teachers' skills and knowledge in designing innovative technology-based learning can impact student learning outcomes. This community service aims to provide training on designing learning using the STEM-based PBL model for teachers at SMP Negeri 18 Palu, Central Sulawesi. This program involved 40 SMP Negeri 18 Palu teachers and was conducted in July 2024. Utilizing a participatory action research approach, this program included material presentations, interactive discussions, and assignments assessed through questionnaires, observation sheets, and assignment sheets. The questionnaires were distributed before training activities, observation sheets were used during training and mentoring activities, and assignment sheets were distributed immediately after the discussion ended. The outcomes of the questionnaire showed that 100% of teachers analyzed learning outcomes and learning objectives before designing the lesson, 90% of teachers were familiar with PBL, 45% of teachers had designed learning using the PBL and implemented it, 10% of teachers had mastered PBL syntax and 100% of teachers had never designed learning with a STEM and combining it with PBL. The observation results were that 100% of teachers in each group played an active role, helped each other and worked together to complete assignments, established good communication with fellow teachers in their groups, and had a high level of responsibility in completing their group assignments. The assignment results show that 100% of teachers succeeded in designing learning using the PBL learning model and integrating it with a STEM approach. This community service's success suggests a continued need for similar training efforts in designing STEM-based PBL models. Expanding workshops to facilitate the implementation of STEM-integrated PBL models in learning is also necessary.

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INTRODUCTION

Teachers are responsible for cultivating a skilled and versatile younger generation, equipped to meet the demands of the 21st century. Therefore, teachers need to improve their competence to become professional teachers who can carry out their primary responsibilities of educating, teaching, directing, guiding, training, evaluating, and assessing (SETNEG, 2005). Article 10 of the 2005 Law on Teachers and Lecturers mandates that teachers must possess, internalize, and master a set of knowledge, skills,

and behaviors to fulfill their professional responsibilities. One of the four competencies teachers must possess is pedagogical competence (Purwandari, 2021). The pedagogical competencies encompass the planning and implementation of educational activities in varied settings, including classrooms, laboratories, and field studies (Permendikbud, 2007). Thus, teachers need to design interesting and engaging learning that can build students' learning motivation to actively interact in learning (Daouk et al., 2016) and improve students' thinking skills and knowledge (Nguyen et al., 2022).

Interesting and enjoyable learning can be realized by implementing innovative learning because it supports conceptual understanding which is essential for high-level performance (Leal-Rodríguez & Albort-Morant, 2019), improves students' ability to think analytically, creative thinking, problem-solving thinking, and critical thinking (Kwangmuang et al., 2021), emphasizes student responsibilities in learning activities such as planning, interacting with teachers, lecturers, and other students, as well as conducting research and evaluating learning (Bakar et al., 2013). Innovative learning models include practical and theoretical learning factors that integrate conceptual and experiential learning related to explicit and implicit knowledge (Chen et al., 2022; Wu & Wang, 2022) using diverse learning media for communication in learning (Hao, 2022) and designed in various ways including designing learning environments, and smart classrooms, choosing the right tools and learning models integrated with applications and social media (Alfoudari et al., 2021). Innovative student-centered learning models include the issue-based learning model known as the model of problem-based learning, abbreviated as PBL (Astuti et al., 2017; Sekarwangi et al., 2021).

A problem-based learning (PBL) involves real problems and provides students the chance to design investigative activities that use problem-solving to conclude (Thomas et al., 1999). The adequacy of PBL in learning has been broadly revealed, including that it can help students develop their insight (Gómez, 2016), enhance the communication abilities of students (Nurbaiti et al., 2016; Sedubun et al., 2019; Setyawan et al., 2021; Shamdas et al., 2023; Wati et al., 2019), reading abilities (Seken & Artini, 2013), writing abilities (Durga & Rao, 2018), metacognitive knowledge, and science learning outcomes (Shamdas et al., 2024), self-academic efficacy, and cognitive learning outcomes (Shamdas, 2023d) as well as self-regulated learning (Shamdas, 2023c). Nevertheless, the use of technology in education today cannot be avoided and significantly impacts the learning process. In addition to being a supplier of limitless admittance to information, innovation is a co-maker of data, tutor, and assessor (Ferdousi & Bari, 2015; Haleem et al., 2022) which is beneficial for constructivist education and instruction targeting solutions for teaching content and pedagogy (Abdulrahman et al., 2020; Greve & Tan, 2021). Thus, it is necessary to incorporate technology into the PBL learning model. Incorporating technology into PBL supports meaningful learning experiences, as using STEM (Science, Technology, Engineering, and Mathematics) in PBL allows students to explore various relevant topics for problem-solving the issues that students are studying.

STEM is a multidisciplinary, integrated approach to teaching (Tanenbaum et al., 2016) that applies science and technology through engineering and arts with mathematical elements (Miyarso, 2019). STEM learning encourages interactive, active learning to improve students' skills in terms of understanding concepts, problem-solving abilities, scientific literacy abilities (Reyza et al., 2020), creative thinking, and critical thinking (Ati et al., 2021; Saputri & Herman, 2022) as well as improving academic achievement (Kong & Matore, 2022) and ALM (Kustiana et al., 2020; Mariano et al., 2021).

Combining STEM with the PBL model effectively enhances both the learning process and student learning outcomes. The effectiveness of STEM-based PBL models on learning processes and outcomes has been widely reported, including research results that

PBL and STEM can increase attitudes, interest, and intrinsic motivation for science and confidence in students' abilities for science and mathematics (Laforce, Noble & Blackwell, 2017), increase metacognitive awareness and decisive reasoning abilities (Shamdas, 2023a) and skills for solving problems (Shamdas, 2023b). Further research shows that integrating STEM into the classroom improves students' ability to answer questions and solve problems, as well as their level of scientific literacy, creativity, and learning outcomes (Pahrudin et al., 2021). In addition, a curriculum integrating STEM PBL can help with language and cultural differences, especially in improving mathematical communication and collaboration skills, such as those experienced by Hispanic students in Texas (Han et al., 2016). Thus, applying the STEM-PBL model is essential for an effective learning process.

Applying the PBL model integrated with STEM provides many benefits. However, not all teachers, including those at SMP Negeri 18 Palu, can apply this approach. Interviews with the school principal and teachers indicated that although some teachers have implemented the PBL model, its application is limited due to time constraints and insufficient mastery of PBL syntax, which causing learning outcomes using the PBL model to be ineffective. Additionally, STEM integrated with PBL has yet to be adopted, as STEM is primarily associated with science and mathematics subjects. Addressing this issue requires teachers to develop skills, creativity, and capability in combining PBL with STEM models.

A suitable approach to support SMP Negeri 18 Palu teachers in this area is through training on designing learning using a STEM-based PBL model. Furthermore, guidance and assistance are needed so that teachers can become accustomed to designing learning using the STEM-based PBL model. Such guidance offers teachers a structured opportunity to create lesson plans utilizing the PBL model based on STEM in all subjects taught at SMP Negeri 18 Palu while receiving feedback from the training team. This allows them to consult directly with the service team regarding challenges in using a STEM-PBL model.

METHODS

The community service activities were held at SMP Negeri 18 Palu, Central Sulawesi, and involved all 40 teachers, including civil servants and honorary teachers. The program was conducted over two days. On June 13, 2024, the service team met with the principal and staff, beginning with a school orientation. The second session was on July 3, 2024, and consisted of the main activities: socialization, training, and assistance in designing STEM-based PBL lesson plans.

A participatory action research (PAR) approach was employed in this project to foster teamwork and facilitate communication within the group (Fogg et al., 2022). The strength of this method lies in its adaptability and the structured division of roles between researchers and participants, which enhances the understanding of the entire process (Mackenzie et al., 2012). The activities included presentations on tips for designing STEM-based PBL models, followed by interactive discussions and assignments on this topic across all subjects. The teachers in attendance were divided into groups based on their subject areas to work on the assigned tasks. The Service Team conducted comprehensive observations of all groups, offering guidance when challenges arose while completing the assignments. At the end of the session, each group presented their project outcomes, allowing other groups to give feedback while the Service Team offered clarifications and reinforcement on all the presented results.

The instruments used in this study included questionnaires, observation sheets, and assignment sheets. Questionnaires, distributed at the beginning of the activity, assessed

participants' understanding and perceptions of STEM-based PBL models in the subjects being taught. Observation sheets were used to record participants' activities' results during the guidance and mentoring process. Assignment sheets, provided during training exercises, documented teachers' design of STEM-based PBL lesson plans. The data collected from the questionnaires, observation sheets, and assignment sheets were analyzed descriptively. The key indicator of success for this activity was whether the teachers could design learning experiences that utilized STEM-based PBL models relevant to the subjects they teach. The output of this community service included a teaching module featuring STEM-based PBL learning for each subject. The PBL learning model was integrated with the STEM approach and comprehensive syntax.

RESULTS AND DISCUSSION

Lecturers from the Biology Education Study Program at FKIP Tadulako University conducted community service activities at SMP Negeri 18 Palu in June and July 2024 under the theme "Improving the Competency of Middle School Teachers through Training and Assistance in Designing STEM-Based PBL Models". The service team numbered four lecturers and was assisted by three undergraduate students in the Biology Education Study Program. The results obtained from this activity are described as follows.

Orientation

The orientation activity was held on June 13, 2024, when the service team visited SMP Negeri 18 Palu. During this visit, the school principal warmly welcomed the team and expressed appreciation for the community service program and its aim to enhance teacher competencies in innovative lesson design to be applied in the Merdeka Curriculum. This orientation activity included an open discussion with the school principal and teachers to finalize details for the community service implementation.

Training and Mentoring

On July 3, 2024, the primary training and mentoring activities commenced with a pre-training questionnaire to assess teachers' initial knowledge of the PBL learning model and STEM. Table 1 shows the results of the analysis of the teachers' answers to the 10 aspects of the questionnaire.

Table 1 Results of the assessment of teachers' prior knowledge of pbl and stem learning models

No	Assessment Aspect	Score (%)	
		Yes	No
1	Teachers always analyze learning outcomes before designing learning activities	100	0
2	Teachers always analyze the learning objectives before designing learning activities	100	0
3	The PBL learning model is familiar to educators	90	10
4	Educators have already created PBL learning models	45	55
5	Teachers are proficient in the PBL learning model's syntax	10	90
6	The PBL model has already been implemented in the classroom	30	70
7	The STEM approach is familiar to educators	20	80
8	Instructors know the importance of each STEM part	05	95
9	Learning has been planned out by teachers using a STEM approach	0	100
10	Instructors have planned to get the hang of utilizing STEM-based PBL models	0	100

Table 1 indicates that all teachers examine learning results and learning objectives before planning their lessons. Almost all teachers at this school are familiar with the

problem-based learning model or PBL. However, less than half of the teachers have designed learning using the PBL model and implemented it, and very few teachers have even mastered PBL syntax. This is the case with teachers' introduction to the STEM approach and each STEM component. The teachers have never designed learning with a STEM approach and combined the PBL model with a STEM approach.

The service team presented materials on the PBL and STEM learning models, which the teachers reviewed attentively. The principal was actively involved throughout the activities. Figure 1 shows the documentation of the presentation process.

Figure 1 The Presentation of material by the service team

The teachers responded with focused attention, actively taking notes and asking insightful questions. Since the teachers were already familiar with the PBL learning model, the important points about using it as reinforcement were explained. The STEM approach and tips for utilizing the STEM-integrated PBL model to design instruction were also explained in depth. An engaging discussion followed the presentation of the material, depicted in Figure 2.

Figure 2 Interactive discussion

The interactive discussion session allowed teachers to express their gratitude for the program and provided them with the opportunity to ask questions (as seen in Figure 2). Some questions were asked about the difficulties in designing PBL learning models and how to solve them. Other teachers asked how to measure the effectiveness of STEM-based learning, how to design STEM-based PBL learning in subjects other than science, and how designing STEM-based PBL learning is linked to learning outcomes. The service team offered comprehensive responses to each question to support the teachers' understanding.

The conversation meeting was trailed by a task to prepare teachers' abilities in planning STEM-based PBL learning models. Teachers were given the group task of designing learning using a STEM-based PBL model in each subject they taught. The teachers were divided into groups according to the subject they taught, such as Science,

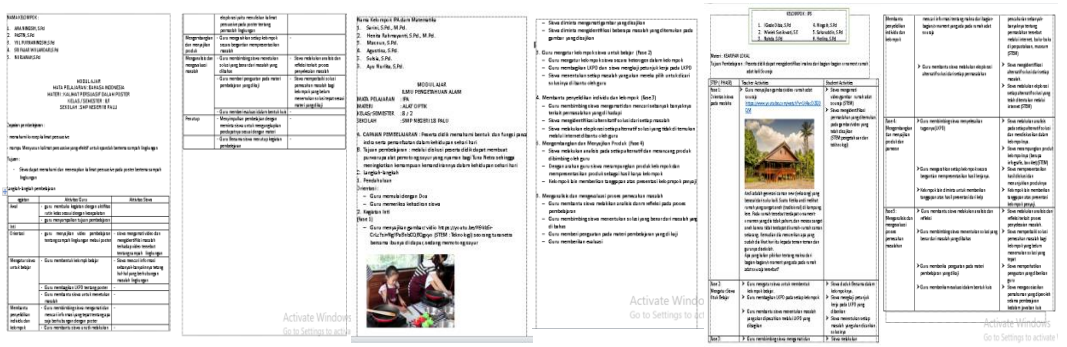
Social studies, and Indonesian language groups. Documentation of the group work process is presented in Figure 3 (a).

The teachers discussed this in small groups accompanied by the Service Team (Figure 3a). The Service Team assisted each discussion group and provided instruction when the group encountered obstacles in completing the tasks. The discussion results were presented in front of the class, and other groups were allowed to respond with suggestions, questions, or other comments. The group discussion results are presented in Figure 3 (b).

(a) (b)

Figure 3 (a) Group work process and (b) The presentation of group work results

One member of the discussion group explained the outcomes of the task in front of the class, and the other groups seriously followed (Figure 53b. The presenting group immediately responded to several questions and suggestions regarding the results presented by the different groups, and the Service Team provided clarification. After the presentation, the Service Team reflected and reinforced every problem found when completing the assignment. The results of group work in designing learning using a STEM-based learning model are shown in Figure 4.



(a) (b) (c)

Figure 4 Results of group work from (a) Indonesian language, (b) Natural sciences, and (c) Social studies

The teachers of SMP Negeri 18 Palu have been able to design learning with the PBL-based STEM model as evidenced by the resulting teaching module, which contains learning activities using the STEM-based PBL model (Figure 4). Several groups were able to complete their assignments until the end of this activity, and all groups fully submitted their assignments via the link provided by the Service Team. The Service Team immediately responded to group assignments submitted by sending certificates to each group member to recognize their cooperation, enthusiasm, and competencies to complete tasks.

The Service Team's assistance in training teachers to organize learning using the STEM-based PBL model was conducive and triggered teachers' enthusiasm to prepare the lessons using the STEM-based PBL learning model. The teachers enthusiastically participated from the beginning of the activities until the end. The Service Team collaborated with the principal and the teachers, as shown in Figure 5.

Figure 5 Group photo of the service team with the principal and the teachers of SMP Negeri 18 Palu

The Principal of SMP Negeri 18 Palu enthusiastically accompanied the service team and teachers from the beginning of the activities until the end (Figure 5). The Service Team successfully stimulated teachers' curiosity about the STEM-based PBL learning model, especially regarding PBL syntax combined with STEM. The teachers, as the participants, maintained their enthusiasm by listening to the Service Team's presentation of the material, engaging in interactive discussions, working on assignments in groups until the end of the activity, and sending complete assignments via the link provided by the Service Team. This activity is also able to build cooperation, collaboration, and communication between teachers as indicated by the results of the Service Team's observations that all teachers in each group participated actively, assisted and worked together to complete tasks, established good communication with fellow teachers in the group, and demonstrated high responsibility in completing group assignments.

The training and mentoring of the Service Team in this Community Service positively impacted the understanding and ability of teachers at SMP Negeri 18 Palu to design learning using the STEM-based PBL learning model. The training and mentoring in designing learning using the STEM-based PBL learning model are supported by the notion that partnership teams from universities need to collaborate and share their expertise with teachers in supporting the development of teacher skills and attitudes to address the needs of all students (Larios & Zetlin, 2023). Mentoring and providing expert support and ongoing collaboration are some efforts to build teacher capacity in professional development and classroom teaching to fulfill the diverse needs of their students and to improve students; thinking skills and intellectual development (Darling-Hammond et al., 2017). The success achieved in this activity is in line with previous reports which informed that Community Services caused science teachers at SMPN throughout Malang City to understand scientific literacy-oriented PBL-STEM and be capable of preparing PBL-STEM-oriented RPPs and practice it in the classroom, as well as PBL-STEM learning can foster student's scientific literacy (Parno et al., 2022). Izzati et al. (2019) reported that 93.75% of participants in Community Service activities stated that the topics presented were interesting and aroused participants' curiosity, resulting in

additional insight and knowledge of participants about STEM approaches. Ramli et al. (2023) also reported that community service activities can increase teachers' knowledge and skills in preparing STEM designs and lesson plans and teachers' perceptions about STEM regarding the required aspects of implementing STEM.

The community service of training and mentoring teachers in designing lessons using the STEM-based PBL model to enhance the skills of junior high school teachers at SMP Negeri 18 Palu received an overwhelmingly positive response from both the principal and the participating teachers. This was evident from the high attendance rates, active engagement in discussions, and participation in questions and answers. Notably, all participants remained in the room until the conclusion of the activities. The school principal was present throughout the event, observing the participants' involvement in all activities until the end. Based on the successes of this program, it is suggested that similar activities should be continued to ensure the development of the teachers' abilities in designing and implementing meaningful learning.

CONCLUSION

The community service activities aimed at training and mentoring teachers to develop lessons using the STEM-based PBL model were successfully implemented with the teachers at SMP Negeri 18 Palu. All teachers have succeeded in designing learning using the PBL learning model and integrating it with a STEM approach.

Based on this community service, it is recommended that this training be expanded to additional schools to support teacher development in STEM-based PBL model design. The STEM-based PBL learning model is necessary to help teachers become accustomed to creating innovative, student-centered, technology-based learning.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

This research involved all authors from the proposal's preparation to the journal's publication: GS conceptualized, MJ methodology, MB validation, RF investigation, GS, MJ, MB, and RF writing—review and editing, GS, MJ, MB, and RF. All authors have read and agreed to the published version of the manuscript.

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