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How to Promote the Ability of Physics Teaching Materials Development through Team-Based Project Learning? An Action Research Evidence

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Abstract

This action research study investigates the use of team-based project learning to enhance the pedagogical competence of pre-service physics teachers, specifically focusing on their capacity to develop physics teaching materials. The study employed a five-stage strategy, which included the following steps: first action, observation, reinforcement, second action, and assessment. These phases formed a cycle of action research in a pedagogical course within the undergraduate program of physics education, specifically focused on teaching material development. Observation, assignments, product assessment sheets, and interviews were utilized to obtain data. The obtained data consists of quantitative data, namely performance value data related to both the process and product, as well as qualitative data in the form of interview findings. The findings indicate that 96% of pre-service teachers who engaged in material development courses through project activities had highly satisfactory marks, namely within the A- and A categories. This study emphasizes the significance of fostering efficient pedagogical techniques among prospective educators and provides data from an action research investigation. Furthermore, this research also assists in the preparation of pre-service physics instructors who possess the necessary skills to create physics textbooks. Participating in collaborative project activities allows pre-service physics teachers to gain essential skills, knowledge, and practical experiences that will prepare them for their future positions in the classroom.

Keywords: pedagogic competency, physics teaching materials development ability, team-based project learning, teaching materials course

INTRODUCTION

The field of education constantly evolves, demanding educators who are well-versed in innovative teaching methods. Education is essential in building society, especially for the next generation, who are knowledgeable and have various supporting skills (Chu et al., 2021). Professional teachers, acting as learning agents, should enhance the quality of national education (Khairiah & Sirajuddin, 2019). Pre-service physics teachers play a crucial role in shaping the scientific literacy of their future students. To effectively prepare these aspiring educators, it is essential to prioritize the development of their pedagogical competence. This article focuses on team-based project learning as a strategy to enhance the teaching abilities of pre-service physics teachers.

In this study, the lecturer leads the interaction between pre-service teachers and the absorbed learning content. According to Shahzad & Naureen (2017), the lecturer or trainer plays a crucial role

in transforming and enhancing the quality of pre-service teachers, as they cannot separate the roles of educating and teaching.

Pre-service teachers must receive training to continuously improve their competence, knowledge, attitudes, and skills in response to advances in science and technology. The aim of enhancing teacher knowledge and skills is to enhance the effectiveness of learning and to influence the learning outcomes of students (Koh et al., 2017; Howe et al., 2019). Therefore, in their role as trainers, lecturers transform various knowledge using approaches, models, strategies, methods, and techniques that align with the development and needs of pre-service teachers. The lecturer must be able to facilitate learning so that all pre-service teachers can be actively involved.

Traditional teacher education methods often fail to equip pre-service physics teachers with the necessary skills to deliver engaging and practical lessons. Many aspiring teachers need more opportunities to apply their theoretical knowledge in real-world scenarios, resulting in a gap between their instructional abilities and the demands of the modern educational landscape. This gap calls for incorporating team-based project learning, providing a platform for pre-service physics teachers to bridge the divide between theory and practice.

Teachers in learning activities often need help with the difficulty of choosing teaching materials, determining teaching materials, and learning materials following pre-service teachers' competencies and characteristics (Ulandari et al., 2019). To achieve competency, the curriculum, syllabus, and teaching materials only provide an outline of the subject matter. Furthermore, the teacher's task is to describe the subject matter so that it becomes complete teaching material (Syamsuri et al., 2017; Nixon et al., 2017). The evidence demonstrates that the teacher must possess the knowledge and skills necessary to create instructional materials, thereby assisting pre-service teachers in achieving the established competencies. Therefore, as a higher education institution that graduates teachers and educators, it is essential to provide knowledge and skills related to developing teaching materials.

According to the literature, lectures in the education study program are generally based on paper assignments, presentations, discussions, and lectures (Blau & Shamir-Inbal, 2017; Hurlbut, 2018). Each group assigns pre-service teachers the task of creating papers and presenting them either offline or online. These methods are useful for specific subjects, but they are not suitable for courses that aim to develop specific skills. Another issue is that lecturers typically deliver lectures based on their own experiences as students. It is very rare for lecturers to attempt to experiment with new and innovative learning ideas without having to adhere to the limitations that may exist in conventional learning approaches. For instance, conducting action research in the classroom aims to enhance the effectiveness of the learning process. Therefore, it is necessary to design lectures that utilize innovative learning models (Oke & Fernandes, 2020). Through action research, will identify effective learning models. Implementing the team-based project model as a learning model can simplify the acquisition of specific skills.

Several studies have revealed that project-based learning can equip specific skills such as critical thinking (Sari & Prasetyo, 2021; Sasson et al., 2018), creative thinking (Umah et al., 2019; Putri et al., 2019), problem-solving (Karan and Brown, 2020; Retno et al., 2019), and others. Project-based learning can also be an effective method in higher education. Research results demonstrate that implementing project-based learning in college can foster the development of practical skills like problem solving, communication, leadership, and teamwork (Jalinus et al., 2020). Project-based learning is also able to increase collegian involvement in relevant and meaningful projects (Santyasa et al., 2020). In addition, by implementing project-based learning, collegians become more prepared to enter the workforce, encourage collaboration between collegians, develop portfolios that reflect their abilities, and provide lifelong learning experiences (Žerovnik and Nančovska, 2021).

Generally, elementary schools, junior high schools, high schools, and higher education use project-based learning extensively. However, the projects only solve problems related to the teaching material. In higher education institutions, the majority of project-based learning models require careful consideration of the model's syntax. Most importantly, pre-service teachers should produce products and answer existing problems. Each syntax of the project-based learning model is a space to equip various knowledge, essential skills, and core skills that form the graduate profile of the significant pre-service teachers. Occasionally, pre-service teachers fail to accurately evaluate the majority of their project products due to inadequate preparation of assessment tools like product and process rubrics.

The assessment of project-based learning must have precise assessment instruments to ensure that the value given to pre-service teachers is authentic, both in process and product assessments.

This study aims to describe the use of a comprehensive project-based learning model, based on the Buck Institute for Education's syntaxes and the assessment rubric, in lectures on the development of teaching materials. The model includes four stages: (1) launching a project; (2) building knowledge, understanding, and skills; (3) developing and revising ideas and products; and (4) presenting products and answering leading questions (Boss & Larmer, 2018). This study aims to provide pre-service teachers with knowledge and understanding about developing teaching materials, equipping them with essential skills, and developing teaching materials that align with the competencies and characteristics of pre-service teachers in senior high schools.

The main research problem addressed in this study revolves around the effectiveness of team-based project learning in promoting the pedagogical competence of pre-service physics teachers. This study aims to identify the impact of collaborative project work on these future educators' teaching skills and content knowledge. Additionally, this study also intends to identify the skills that pre-service physics teachers must have in developing physics textbooks.

METHODS

To gather evidence, an action research approach was employed. The study involved a group of pre-service physics teachers actively in team-based project learning. Data collection methods included observations, interviews, and the analysis of lesson plans and student artefacts. These multiple data sources allowed for a comprehensive examination of the participants' pedagogical growth and the impact of their project-based learning experiences.

This type of research is linear action research because it only consists of one cycle (Acharya & Mohanty, 2019). The reason for using this type of research is because action research is one of the strategies that can find realistic solutions to difficulties and problems in the learning process. This is in line with researchers as well as lecturers still trying to find more effective ways of teaching, adjusting learning materials to the needs of students by implementing innovations in learning. The stages in this research are planning, conducting, observing, providing reinforcement, and assessing, as shown in FIGURE 1.

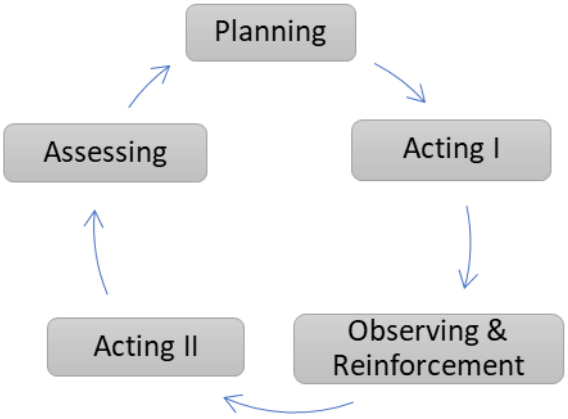

FIGURE 1. Research Design

The activities carried out at each stage of the research are as shown in FIGURE 1: (1) At the planning stage, the researcher prepares semester lesson plans, assessment instruments, and main topics for learning. (2) At the acting stage, the emphasis is on student activities, namely conducting learning with a team-based project model at the stage of launching projects, building knowledge, understanding, and skills, and making the project's initial design. (3) At the observing and reinforcement stage, the researcher monitors and accompanies pre-service teachers, collects preliminary design data for the project, provides reinforcement related to the initial design, and makes recommendations for improvements to the initial design. (4) At the Acting II stage, pre-service teachers continue learning with a team-based project model while developing and revising ideas and products, presenting

products, and answering guiding questions. (5) In the final stage, namely assessing, conducting a final assessment including performance and product evaluations.

The research was conducted in the Physics Education Study Program at a state university in Surabaya, Indonesia. The time used in this research is one semester or four months. The population of this study was pre-service teachers of the Physics Education Study Program who programmed a physics pedagogical course, namely Physics Teaching Material Development. The research sample was 25 pre-service physics teachers selected by purposive sampling. This is because this research is only aimed at pre-service physics teachers who take teaching material development courses and also limited population.

Data were collected using process performance appraisal sheets, product performance appraisal sheets, and interview sheets. Performance assessment sheets assess student activity during the learning process and project work. The product assessment sheet assesses the products resulting from project activities. The interview sheet is used to obtain student information regarding implementing learning. The number of interview questions is 8 questions covering 4 aspects, namely related to Experience in Teams and Cooperation, Challenges and obstacles, Learning and Skill Development, Evaluation and Suggestions for Improvement. Interviews were conducted on representatives of each team, namely 12 prospective physics teachers. The time needed for the interview is approximately 2 to 3 minutes.

All instruments have been validated by 3 expert validators in which the validated aspects are Construct Validity, Content Validity and Reliability. In addition, expert validators also assessed the consistency of the instrument to determine the suitability of the instrument with the research objectives and concepts being measured. Based on the validation results that the research instrument is feasible to use. Furthermore, the data obtained were processed and analysed descriptively. The results of the data analysis were divided into four categories: the value of participation and activeness at 20%, the value of the task at 30%, and the value of the product result at 50%.

RESULTS AND DISCUSSION

Planning Stage

In the planning stage, lecturers collaborated to develop project-based lesson plans. This involved identifying learning objectives, selecting appropriate activities, and designing assessment strategies. The participants could combine their subject knowledge and pedagogical expertise by working in teams to create engaging and comprehensive lesson plans.

Initially, the lecturers compile and design activity plans for one semester as a reference for implementing learning. The summary of team-based project learning activities is concluded in 16 lectures or weeks, which are part of the learning stages for one semester. The 16 lectures were divided into four group stages of team-based project learning. Stages one, lectures 1 - 4, building knowledge and understanding of the textbook framework. Stages two, lectures 5 - 8, project design with design presentation as an assessment task. Stages three, lectures 9 - 12, project development. Stages four, lectures 13 - 15, presenting the designed textbook as a final product of the teaching material development project. Rubrics for assessing all the stages were prepared based on performance activities and outcomes.

Action Stage I

At this stage, lecturers implemented their project-based lesson plans in actual classrooms. Through hands-on experience, they could apply their theoretical knowledge and adapt their instructional strategies based on the needs and responses of the students. This stage allowed them to observe the practical challenges of teaching and adjust accordingly.

Project-based learning is carried out at this stage, from the project launch stage to the design stage of the teaching material framework. This stage is emphasized to equip pre-service teachers with knowledge and skills in designing and developing the products to be produced. After launching the project, the lecturer provided several materials related to the steps and principles of developing teaching materials. Furthermore, pre-service teachers carry out curriculum analysis to find topics that will be developed as teaching materials. In addition, based on the results of the curriculum analysis, pre-service

teachers formulate learning objectives as a reference in developing the selected teaching materials. Also, at this stage, pre-service teachers analyze at least two textbooks used by high school students, as shown in FIGURE 2.

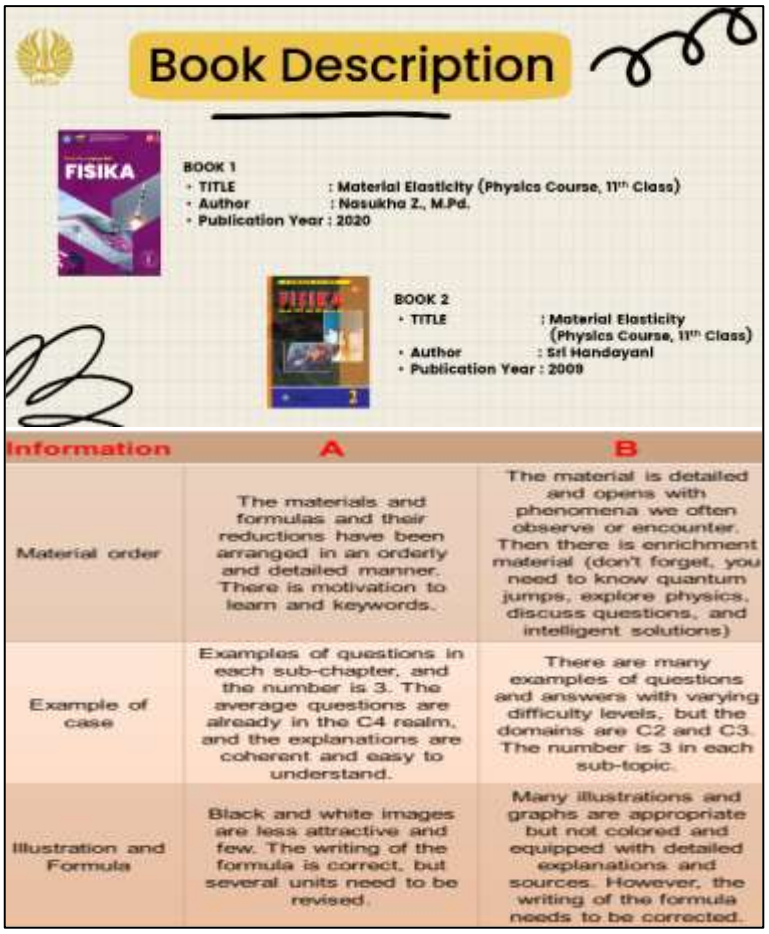

FIGURE 2. An example of the results of the analysis carried out by pre-service teachers.

FIGURE 2 shows the results of one group's analysis of high school physics textbooks. The results of this analysis are presented in front of the class as a form of accountability for what has been done by each group. Each group gets input from the lecturer and other groups. Furthermore, based on the results of the presentations and discussions and input from the lecturers, pre-service teachers were directed to design a textbook framework in the form of a macrostructure, as shown in FIGURE 3. FIGURE 3 is an example of a textbook design designed by pre-service teachers. The textbook framework is used as a reference in developing textbooks. In the other group, the designed macro structure contains material or physics concepts and learning activities that lead to student-centred learning.

Observing and Reinforcement Stages

Throughout the project, the lecturers were closely observed and provided with feedback and reinforcement. Experienced observers or colleagues, offering suggestions for improvement and reinforcing effective teaching practices. At this stage, the lecturer examines all the draft textbooks designed by all groups regarding the curriculum in high school used by pre-service teachers, presenting the results of their respective designs. It is essential because the textbook framework is the basis for developing textbooks. Also, at this stage, the lecturer provides several improvements and recommendations to each group to make the textbook framework's design more appropriate for reference. The reinforcement given at this stage is that the lecturer displays several examples of standard textbooks. This effort was a stimulus for each group so that the framework of the designed

textbooks was more exciting and different from existing books so that the developed books could be claimed as innovations by the pre-service teachers themselves.

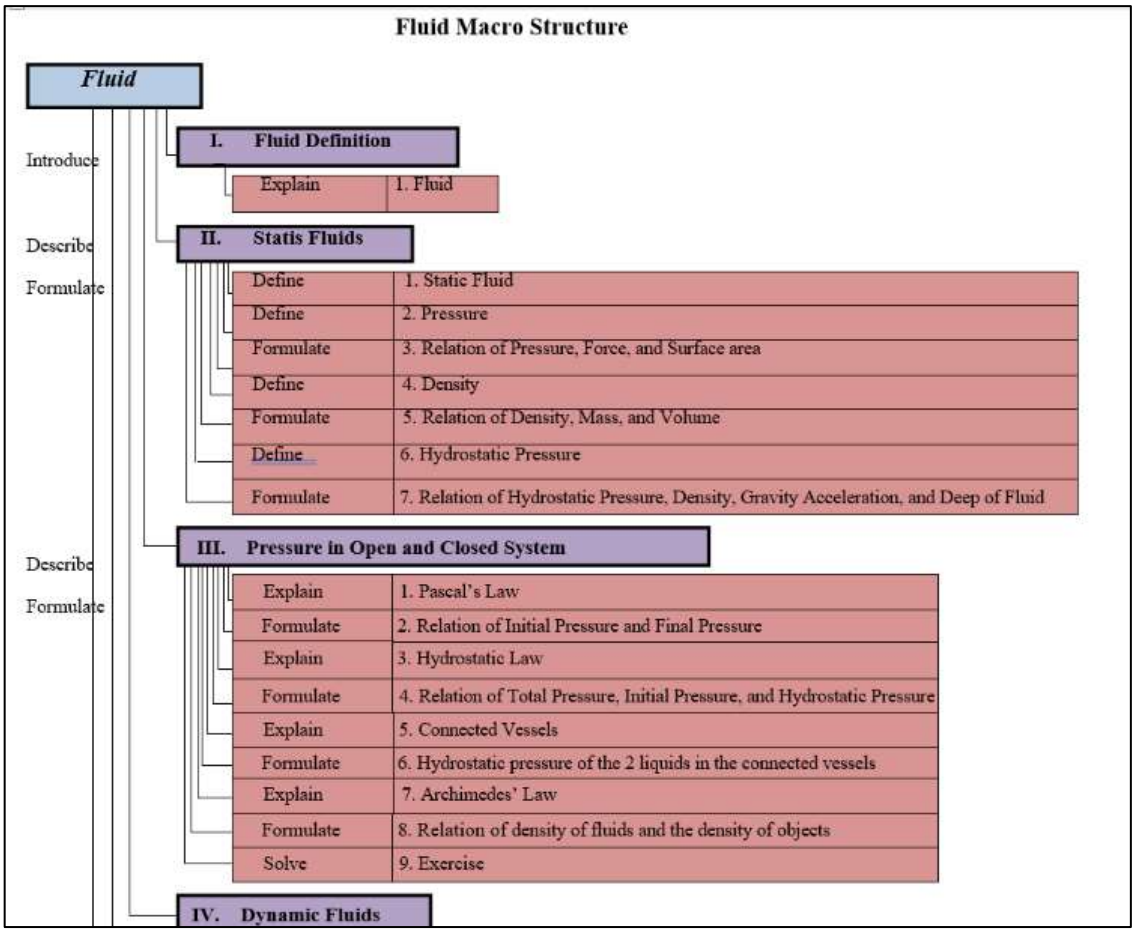

FIGURE 3. An example of a design result in the form of a macrostructure.

Action Stage II

The lecturers implemented revised lesson plans in this stage, considering the feedback and insights gained from the previous stages. By incorporating the feedback and lessons learned, they could refine their teaching strategies and tailor them to the specific needs of their students.

This stage is the development stage in which each group develops textbooks based on the previously designed framework of the book. The product criteria produced are having an attractive appearance, including cover design, appearance or background, and layout. In the introduction, there are (1) a brief description, benefits, and relevance; (2) competency formulation or learning objectives; (3) the order of discussion and relation to the material presented with the concept map; (4) study guides for both pre-service teachers and teachers. In the core section, there are (1) a description of the subject matter; (2) examples of questions and their solutions; (3) Illustrations or images that match the content; (4) learning activities oriented towards the use of innovative learning models (inquiry, PBL, and PjBL); (5) tasks or exercises; and (6) formative tests; and (7) Summary. Meanwhile, in the closing section, there are (1) the most up-to-date bibliography, (2) the index, (3) the glossary, and (4) the answer key. Based on these criteria, all groups have fulfilled them, and as an example of the appearance of the textbook cover from an exciting group, as shown in FIGURE 4.

The development of textbooks was carried out for six weeks, where each week at a mutually agreed time, each group provided a report on the project's progress. Based on the results of observations while developing textbooks, progress reports were beneficial for each group, especially for groups facing problems. The obstacles faced by almost all groups are in the presentation of learning activities. Pre-service teachers tend to present learning activities in simple experimental activities that aim only to

confirm the concepts taught. However, after going through revisions based on input during the progress report on learning activities, it became better where learning activities were no longer just confirming the concepts being taught and carried out at the end of the meeting. Learning activities have led to a student-centric approach, where the stages of learning activities use stages of learning models such as inquiry, PBL, and PjBL.

FIGURE 4. One example of the final product of a project activity is a textbook.

Evaluation Stage

The final stage involved evaluating the overall effectiveness of team-based project learning in promoting pedagogical competence among pre-service physics teachers. This assessment included observer feedback, participant self-reflection, and a comparative analysis of students' performance in project-based and traditional assessments. The results highlighted the positive impact of team-based project learning on the pre-service teachers' teaching skills and subject knowledge. After each group produces a product in the form of a textbook, a product presentation is carried out at the 15th and 16th meetings to assess the final product produced. Based on the results of the product assessment, in general, the final product produced by each group follows the agreed textbook criteria. This stage also evaluates all processes passed by all groups based on data on activity, participation, assignments, process performance, and product performance, as presented in TABLE 1.

TABLE 1. Summary of the final grades for the development of teaching materials.

	Participation	Assignment	Product	Final Value
Mean	86.24	84.92	84.04	84.744
Min	70	70	42	56
Max	95	87	88	88.6
$n \geq 85$	22	23	20	20
$75 \leq n < 85$	3	2	4	4
$n < 75$	0	0	1	1

Based on TABLE 1, it can be explained that from a series of lectures on developing teaching materials using team-based project learning, it is clear from the 25 pre-service teachers that 80% of pre-service teachers get grades above 85 or get grades A, 16% of pre-service teachers get grades between 75 and 86 or get an A-, while one person gets a relatively low score of 56 or a grade C. This data indicates that lectures using the team-based project method effectively teach material development lectures.

From a series of lecture activities, indirectly, pre-service teachers practice their pedagogical competence as pre-service teachers. Pre-service teachers understand learning theories, teaching-learning principles, effective learning methods, and how to facilitate an effective learning process (Murkatik et al., 2020; Yusnita et al., 2018; Mukhamadovna et al., 2020). It can be seen from the textbook products produced that in the learning activities section, they use effective learning models. Likewise, the ability to plan learning according to student needs, in this case, is also clearly seen in textbooks where the determination of learning objectives is evident, and the organization of learning content is exciting (Sudargini & Purwanto, 2020; Ismail & Jarrah, 2019). In addition, pre-service teachers can also design relevant evaluation instruments and apply appropriate evaluation techniques according to their level of understanding of pre-service teachers (Uerz et al., 2018).

In addition, based on the results of the analysis of observations made during the implementation of the team-based project learning model in teaching material development lectures, many positive impacts were found, including (1) Good collaboration and teamwork occurs, where pre-service teachers work together in groups to complete the planned project. It encourages pre-service teachers to develop effective collaboration, communication, and teamwork skills (Hussein, 2021; Baser et al., 2017). This ability is invaluable in the world of work, where team collaboration is becoming increasingly important. (2) The development of interpersonal skills occurs; this can be seen during the delivery of project designs and during project progress workshops where pre-service teachers practice listening skills, understand other people's points of view, respect differences, and resolve conflicts (Saenab et al., 2018; Konrad et al., 2020). It helps prepare them for work situations where they have to work with various individuals. (3) The occurrence of active and participatory learning, where pre-service teachers are actively involved in the learning process. They receive knowledge from the lecturers, sharing ideas, discussing, and solving problems together (Sormunen et al., 2020; Mahasneh & Alwan, 2018). It can improve understanding and retention of learning materials. (4) There is independence in solving problems involving critical and creative thinking skills. In this case, it can be seen when pre-service teachers face challenges or projects requiring problem-solving where they can involve critical thinking, analyze situations, and find practical solutions (Anazifa & Djukri, 2017; Fiteriani et al., 2021). This ability is an essential aspect of a teacher's professional development in dealing with changes in the work environment.

In addition to these positive impacts from a series of learning using the team-based project model, several important things must be paid attention to because they can make learning more meaningful. The diversity of ideas and perspectives will open opportunities to see problems or projects from various perspectives, broaden horizons, and reach more innovative and comprehensive solutions. Thus, learning will occur on an ongoing basis to create an environment where pre-service teachers are actively involved in the learning process and provide feedback to each other. Through team reflection and evaluation, they can identify their strengths and weaknesses and develop an action plan for future improvement. It encourages continuous learning and self-development. Therefore, implementing a team learning model can provide long-term benefits for pre-service teachers, helping them develop the skills and attitudes needed in an increasingly complex world of work.

Based on interview results, while related to pedagogical competencies that are equipped through team-based project learning in this case, namely the ability to develop physics textbooks, it is clear that students are supplied to have several things, namely (1) knowledge of Physics concepts, a strong understanding of physics concepts is needed to avoid misconceptions and present comprehensive material; (2) the ability to prepare learning materials, this is needed so that they are able to compile well-structured learning materials, starting from basic concepts to higher complexity, and are able to design logical and integrated learning sequences; (3) creativity, this is needed to create interesting learning materials by involving the use of various types of media, examples, illustrations, and

interesting learning activities; (4) good writing skills, this is needed to convey physics concepts clearly and effectively presented with good sentences and paragraphs, and using language that is easily understood by the target readers; (5) ability to adapt materials to the curriculum, this is needed to be able to adapt learning materials to the applicable curriculum by understanding the curriculum standards in advance and ensuring that the materials presented are in accordance with the established learning objectives; and (6) understanding of educational technology, this is needed to be able to utilize technology to enhance students' learning experience, for example by incorporating multimedia, online-based learning, integrating augmented reality technology, and so on. Of course, having these competencies or skills will greatly help prospective physics teachers in designing and developing teaching materials, especially physics textbooks that suit the needs of students. This is in line with the curriculum being used in Indonesia, namely the independent curriculum where teachers are required to teach students according to their needs.

CONCLUSION

The findings of this action research provide strong evidence that team-based project learning is a practical approach to promoting pedagogical competence among pre-service physics teachers. By engaging in collaborative projects, lecturers can enhance their subject knowledge, develop instructional strategies, improve student engagement, and manage classroom dynamics effectively. Based on the results and discussion, lectures through the team-based project method are very feasible to equip pre-service teachers with pedagogic competencies. Pedagogic competence is provided during the project work process and through the products produced. Not only pedagogic competence but many other abilities are provided, such as collaboration and teamwork skills, interpersonal skills, independence in problem-solving, and skills in graphic design. However, this research has limitations, namely that not all pedagogic competencies can be equipped in this research. The most visible competencies are competencies in mastering learning concepts, learning planning, and learning evaluation, while classroom management competencies and learning implementation have yet to become a focus. The contribution of this research is undoubtedly beneficial for developing the pedagogic competence of pre-service teachers. In addition, the lecture model can be used as a reference in lectures for other similar subjects. Recommendations for further research can dig deeper into how to equip teacher competencies where not only pedagogic competencies but other teacher competencies simultaneously through group project-based lectures without compromising the essence of the final achievement of the course. The results of this study highlight the potential of team-based project learning as a valuable tool in teacher education programs, bridging the gap between theoretical knowledge and practical application. As we strive to equip future physics teachers with the skills necessary for effective instruction, incorporating team-based project learning into teacher education programs emerges as a promising avenue.

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