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Enhancing Science Education in Primary Teacher Training: An Analysis of Course Implementation and Pedagogical Practices

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ABSTRACT

Improving the quality of science education in teacher training is essential for developing competent educators. This study focuses on enhancing science instruction within the Primary School Teacher Education program at a private university in Serang City, Banten, by examining the implementation of the science course and related pedagogical practices. A descriptive qualitative approach was employed, involving five sixth-semester pre-service teachers as participants. Data were collected through structured interviews lasting 30–45 minutes. The interviews explored multiple facets of the course, including syllabus availability, lesson plan alignment, instructional media usage, access to teaching materials, application of instructional models, learning activity sheets, assessment practices, and course activities. Findings indicate inconsistencies between course plans and classroom activities. Participants reported limited access to teaching resources and inconsistent use of instructional media. However, they emphasized the value of interactive activities and the need for varied assessment tools. Feedback highlighted the importance of structured syllabi, engaging media, and creative approaches that align with different learning styles. The results underscore the importance of student input in improving science education courses. Enhancements should focus on providing comprehensive instructional materials, integrating technology, and promoting pedagogical creativity. Diverse teaching strategies and assessment methods can foster active engagement and support the professional growth of pre-service teachers. Structured, student-informed improvements in course design and delivery are essential to prepare effective future educators, especially in science education.

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1. INTRODUCTION

Science is a structured and interconnected body of knowledge focused on understanding natural phenomena. Its growth is indicated by the accumulation of facts and the "scientific method," a systematic approach that spans various disciplines to explore the natural world (Ault & Dodick, 2010). This methodology involves formulating hypotheses, conducting experiments, and analyzing data, allowing for objective and replicable research that minimizes biases and leads to discoveries. As a result, science continuously enhances our understanding of the world.

The dynamic process of discovery is at the heart of science. This involves acquiring facts and concepts and cultivating "scientific attitudes," such as open-mindedness, scepticism, and inquiry (Husain & Khan, 2024). These attitudes are crucial for developing critical thinking and problem-solving skills across various disciplines, ensuring that scientific inquiry remains adaptable and rigorous. Recent studies have emphasized the importance of educational methods, such as problem-based and inquiry-based learning, in fostering scientific attitudes among students. These approaches promote active engagement, critical thinking, and the application of the scientific method, leading to deeper learning and understanding (Antonio & Prudente, 2024).

Science education aims to provide students with the skills and knowledge necessary to comprehend themselves and the natural world while also enabling them to apply this understanding in real-life situations (Antonio & Prudente, 2024; Fitriani et al., 2020). This learning emphasizes hands-on activities that engage students with scientific principles directly. Through these practical experiences, students develop the critical competencies to investigate and interpret the natural environment using a systematic scientific approach (Lederman & Lederman, 2019; Furtak & Penuel, 2019a). Science education lays the groundwork for critical thinking, problem-solving, and data-driven decision-making in professional settings. These skills are crucial across healthcare, engineering, and environmental management, where scientific principles are applied to solve complex problems. Science drives technological innovation, enhances public health strategies, and supports environmental solutions (Walsh et al., 2020).

The science education course is a key part of the Bachelor's program in Primary School Teacher Education, equipping pre-service teachers with essential knowledge and skills for teaching science at the primary level. Offered in the fifth semester with three credits, this mandatory course focuses on preparing students to design, implement, and assess science instruction aligned with curriculum standards. It emphasizes using appropriate methods and approaches to foster scientific skills in students, tailored to their developmental stage.

In addition to mastering scientific content, pre-service teachers must also apply effective pedagogical strategies guided by the Technological Pedagogical Content Knowledge (TPACK) framework. TPACK integrates technology, pedagogy, and content, enabling future teachers to create innovative and relevant learning experiences (Lachner et al., 2021). TPACK includes effectively using technology and teaching aids to enhance science instruction and achieve curriculum goals.

The TPACK approach can be systematically implemented within pre-service teacher education by integrating three core components: content knowledge, which represents the subject matter expertise; pedagogical knowledge, which involves strategies and methods for effective instruction; and technological knowledge, which refers to the ability to utilize technology in educational settings. This integration enables pre-service teachers to design and deliver meaningful learning experiences. They learn to leverage technology as a valuable tool to facilitate students' understanding of complex concepts, enhancing the overall educational experience in a contemporary learning environment.

Pre-service teachers should receive training in critically evaluating technological tools to ensure that they align effectively with their students' learning needs and characteristics. The successful implementation of TPACK framework necessitates that pre-service teachers comprehend the learning context, considering various factors, including students' cultural, social, and environmental backgrounds. This comprehension enables them to tailor technology and instructional strategies, fostering inclusive and meaningful learning experiences. Such an approach not only enhances the professional competencies of pre-service teachers but also equips them to confront the challenges posed by education in the digital era.

Teachers proficient in TPACK are expected to specialize in science content and adopt modern pedagogical practices incorporating technology. This approach fosters active, creative, and contextual learning, helping students develop a deeper understanding of scientific concepts and essential real-world skills (Alrwaished et al., 2020).

Analyzing science education courses is crucial for enhancing teaching quality and preparing pre-service teachers to meet contemporary educational challenges. This analysis helps institutions identify strengths and weaknesses in course design, teaching methods, and approaches, paving the way for more effective improvements. First, course evaluations allow for aligning materials with national curriculum developments, ensuring that pre-service teachers master relevant science content and pedagogy. By incorporating frameworks like Technological Pedagogical Content Knowledge (TPACK), pre-service teachers are better equipped to integrate technology into their teaching, a critical skill in modern education. Additionally, this analysis assesses pre-service teachers' readiness to implement science instruction, enabling more targeted training to improve their ability to design, deliver, and evaluate compelling learning experiences. Overall, these efforts enhance lecture quality and better prepare pre-service teachers to provide meaningful, engaging education for their students.

2. METHODS

This study adopts a descriptive qualitative approach to examine the science education course within the Primary School Teacher Education program at one of the private universities in Serang City, Banten. Qualitative research emphasizes understanding the meanings and interpretations of participants' experiences, allowing researchers to derive insights from observed phenomena (Muzari et al., 2022). This analysis seeks to offer valuable perspectives to improve the science education curriculum. By exploring pre-service teachers' experiences and viewpoints, the study aims to enhance the overall quality of teacher preparation. Furthermore, it aligns with contemporary educational research trends, which underscore the significance of incorporating student feedback into curriculum development and teaching strategies.

The study focuses on 6th-semester pre-service teachers who have completed the science education course, chosen for their relevant experiences and insights. Employing purposive sampling—a widely used technique in qualitative research that selects participants based on their capacity to provide rich data; the study includes a sample of five pre-service teachers to capture diverse perspectives. The primary aim is to examine the delivery of the science education course, evaluating various elements such as curriculum materials, instructional methods, and the overall effectiveness of teaching practices implemented.

This study presents a limitation due to its small sample size, comprising only five participants. Such a limited number may not adequately reflect the broader population, thereby suggesting that the findings may represent the experiences and perspectives of a select few individuals. This limitation restricts the generalizability of the results to all pre-service teachers. Also, it affects external validity, which pertains to the applicability of the study's findings to larger contexts or groups.

Nevertheless, qualitative research typically emphasizes the depth and relevance of the data over generalizability. Consequently, despite the small sample size, the study can yield meaningful insights into implementing the science education course. The internal validity of the research is preserved through the meticulous selection of participants, ensuring that their perspectives are pertinent and informative.

In this study, structured interviews were conducted with all participating pre-service teachers. Each pre-service teacher was asked the same set of questions designed to explore various aspects related to the implementation of the science education course. Interviews were conducted individually, with each session lasting between 30 and 45 minutes per participant. These interview questions have been organized in a table format to facilitate understanding and further analysis of the aspects related to pre-service teachers' experiences and perspectives on the science education course. This table offers

a comprehensive overview of the essential aspects that should be considered to enhance and develop educational quality within this context.

Table 1. Aspects of the implementation of the science education course

Aspect	Description
Syllabus and Lesson Plan Availability	Evaluates whether a comprehensive syllabus and lesson plan are provided, detailing course objectives, topics, and expectations.
Alignment of Course Activities with Syllabus and Lesson Plan	Assesses the degree to which course activities are aligned with the syllabus and lesson plan.
Provision of Learning Activity Sheets	Investigate the availability of learning activity sheets that guide both instructors and students through the learning process.
Access to Teaching Materials/Modules	Reviews the accessibility and appropriateness of teaching materials, including textbooks and online resources.
Use of Instructional Media	Analyzes the use of instructional media such as videos, presentations, and digital tools to enhance teaching.
Learning Evaluation	Examines the evaluation methods used at the conclusion of the course, including assessments and feedback mechanisms to measure student understanding and course effectiveness.
Application of Instructional Models	Assesses the pedagogical approaches employed, focusing on models that encourage active learning and critical thinking.
Course Activities	Describes the range and type of course activities, such as lectures, group work, and hands-on experiments, aimed at creating an interactive learning environment.

This structured approach to the interview questions aims to collect thorough feedback on the science education course. The research identifies strengths and areas for improvement within the course framework by concentrating on these key aspects, thereby enhancing teacher preparation programs (Husband, 2020). Involving students in this evaluation process aligns with best practices in educational research, highlighting the significance of stakeholder input.

This study employs data triangulation to ensure the reliability of findings by comparing and verifying information from interviews. The analysis follows Miles's (1994) three-step process:

1. Data Reduction: Key information relevant to the research is summarized, removing unnecessary details to simplify and organize the data.
2. Data Display: The reduced data is presented in an organized format, such as charts or summaries, facilitating pattern recognition and insight generation.
3. Conclusion Drawing and Verification: Initial conclusions are drawn from the data, then revisited and refined as further analysis ensures their accuracy.

This method ensures that findings are well-organized, evidence-based, and reliable.

3. FINDINGS AND DISCUSSION

The results obtained from the research have to be supported by sufficient data. The research results and the discovery must be the answers, or the research hypothesis stated previously in the introduction.

3.1. Syllabus and Lesson Plan Availability

The table below summarizes each respondent's responses on the syllabus and lesson plan availability in the science education course.

Table 2. Respondent's responses on the syllabus and lesson plan availability

Respondent	Response
1	Syllabus and Lesson Plan were not provided; course structure was explained verbally and written notes were on the board.
2	Lecturer provided a general overview of the course.
3	Lecturer outlined the course structure from beginning to end on the board.
4	Syllabus and Lesson Plan were not provided; information was written on the board.
5	Syllabus and Lesson Plan were not available; the course was explained verbally with notes on the board.

The table reveals that most respondents indicated that the syllabus and lesson plan were not directly provided, with course structure primarily communicated through verbal explanations or notes on the board. No written materials, such as a formal syllabus, were distributed, and the lecturer relied on informal methods to convey the course content. This lack of formal documentation may affect students' understanding of the course objectives and structure, potentially limiting their ability to plan and engage effectively throughout the semester. Observations show that the lecturer has not provided a detailed syllabus or lesson plan, instead offering verbal explanations and board notes. This approach may be insufficient, as these documents are critical for structuring the course and guiding students (Kumarassamy & Koh, 2019; Iqbal et al., 2021).

A syllabus and lesson plan are essential for clarifying course objectives, topics, and activities, offering students a clear roadmap for successful learning (VanTassel-Baska & Baska, 2021). Without these, students may lack understanding of the course structure and the competencies they need to develop, leading to confusion and difficulty connecting the material to real-world applications. Additionally, the absence of a structured plan can reduce student engagement, making them passive learners focused on tasks rather than more profound understanding, ultimately impacting their motivation and course quality (Barkley & Major, 2020).

The lack of a detailed syllabus and lesson plan can negatively affect student learning, causing reduced engagement, unclear objectives, and limited motivation. These essential documents can significantly improve students' understanding of the course, keep them engaged, and ensure they acquire the necessary skills and knowledge throughout the semester.

Several concrete solutions can be implemented to address the lack of a structured syllabus and lesson plan. First, develop a clear and detailed syllabus that outlines learning objectives, topics, and relevant activities. Each session should include a specific lesson plan that detail teaching methods and assessments. Communicating the learning objectives at the beginning of each class will help students understand what is expected of them. Online learning platforms such as Google Classroom can enhance students' access to information and learning materials. Regular feedback and encouraging discussions about the material will also increase student engagement. Flexibility in teaching is essential to adapt the content to meet students' needs, resulting in a more organized, clear, and motivating learning experience.

3.2. Alignment of Course Activities with Syllabus and Lesson Plan

The table below summarizes each respondent's responses on aligning course activities with the syllabus and lesson plan in the science education course.

Table 3. Respondent's responses on alignment of course activities with syllabus and lesson plan

Respondent	Response
1	Course activities are consistent with the lecturer's prior explanation.
2	Activities align with the explanation previously provided by the lecturer.
3	Activities are in accordance with the lecturer's previous explanation.
4	Activities match the explanation given earlier by the lecturer.
5	Activities are consistent with or follow the sequence outlined in the lecturer's prior explanation.

Pre-service teacher's feedback reveals that, despite the absence of a formal syllabus and lesson plan, course activities are systematically conducted in alignment with the lecturer's established sequence. The lecturer's consistent adherence to the structured framework fosters a well-organized and purposeful learning environment, allowing students to engage with course content confidently, supported by clear guidance at each instructional stage.

This feedback highlights the critical role of the instructor in ensuring alignment between course activities and intended learning outcomes. Such alignment is essential for meeting educational objectives and cultivating a coherent and seamless learning experience. Through structured guidance, students are better positioned to follow the instructional flow, leading to a more comprehensive and profound grasp of the subject matter.

3.3. Provision of Learning Activity Sheets

The table below summarizes each respondent's responses on the provision of learning activity sheets in the science education course.

Table 4. Respondent's responses on the provision of learning activity sheets

Respondent	Response
1	No specific worksheets; verbal guidelines provided for group projects (eco-prints).
2	No worksheets are available; reflection activities are conducted, and guidance is provided verbally and on the board.
3	No worksheets; written and verbal instructions provided for project stages.
4	No worksheets; guidance is given in written form on the board, and verbal explanations are given.
5	No worksheets provided for individual or group assignments.

The table highlights the absence of learning activity sheets in the science education course, with project guidance primarily delivered through verbal instructions and board notes. Despite the course's focus on project-based learning, this lack of worksheets is concerning, as they are essential tools for supporting interactive, hands-on activities. Worksheets provide structured guidance, helping students follow a logical sequence, meet learning objectives, and apply a scientific approach to problem-solving (Muskita & Subali, 2020).

Research suggests that learning activity sheets enhance student engagement, promote critical thinking, and facilitate effective student-lecturer interaction, which is crucial for deepening understanding of scientific concepts (Kahar et al., 2021). In courses emphasizing practical skills, learning activity sheets help ensure alignment between classroom activities and competency standards, contributing to the coherence of the course and improving learning outcomes (Jin et al., 2019). Without learning activity sheets, students may struggle to engage fully with the content and achieve the desired learning outcomes. Incorporating well-designed worksheets would enhance both the learning experience and the effectiveness of the teaching process, leading to better educational results.

3.4. Access to Teaching Materials/Modules

The table below summarizes each respondent's responses on access to teaching materials/modules in the science education course.

Table 5. Respondent's responses on access to teaching materials/modules

Respondent	Response
1	No modules or printed books available.
2	Softcopy books are available after the midterm exam (not compiled by the lecturer).
3	Softcopy books provided (authored by someone other than the lecturer).
4	Softcopy book available.
5	Softcopy book available.

In summary, none of the respondents reported receiving printed books or modules, though most mentioned the availability of softcopy books, which were not authored or compiled by the lecturer. In some cases, these materials were provided after the midterm exam.

This highlights the importance of offering teaching materials prepared explicitly by the lecturer, ensuring alignment with course objectives and competencies. Adequate teaching resources go beyond knowledge, incorporating the skills and attitudes students need to achieve course goals (Biggs et al., 2022). Distributing these materials before the course begins allows students to familiarize themselves with key concepts, enhancing their readiness for active participation and fostering a more interactive learning experience. By preparing original materials in advance, lecturers promote deeper learning and encourage student engagement (Yilmaz & Korur, 2021).

3.5. Use of Teaching Media

The table below summarizes each respondent's responses on using teaching media in the science education course.

Table 6. Respondent's responses on the use of teaching media

Respondent	Response
1	PowerPoint presentations, whiteboard, educational videos
2	PowerPoint presentations, whiteboard
3	PowerPoint presentations only
4	PowerPoint presentations in several sessions
5	PowerPoint presentations in a few sessions

The excerpt highlights the current limitations of teaching media, primarily consisting of PowerPoint presentations and whiteboard use. Expanding the range of instructional media could enhance student learning by addressing engagement and challenges to learning outcomes. Research indicates that well-chosen media significantly improves student attention and comprehension. Incorporating interactive or multimedia tools can increase student interest and motivation, leading to better focus and more profound understanding (Karahan & Roehrig, 2016).

Selecting media that aligns with course content and student needs facilitates effective learning (Nicolaou et al., 2019). Lecturers can utilize existing resources or develop custom, cost-effective media tailored to specific teaching objectives, leading to more organized and impactful lessons.

Integrating diverse, high-quality teaching media can significantly improve the classroom experience, fostering greater student engagement and understanding while enhancing teaching effectiveness and communication (Dittmar & Eilks, 2019).

3.6. Learning Evaluation

The table below summarizes each respondent's responses to the learning evaluation in the science education course.

Table 7. Respondent's responses on learning evaluation

Respondent	Response	
	Evaluation Methods	Frequency
1	Oral tests, project assignments, written exams	Oral tests after each class, midterms, and finals
2	Oral evaluations, project presentations, written exams	Oral evaluations each class, midterms, and finals
3	Games-based evaluations, written exams	Games after presentations, midterms, and finals
4	Written exams, Q&A during project presentations	Midterms, finals, and project presentations
5	Games-based evaluations, written exams	Games after each class, midterms, and finals

The responses indicate a range of evaluation methods used in teaching, including oral assessments, games, and Q&A sessions following presentations, alongside formal written exams during midterms and finals. Evaluation plays a crucial role in education, assessing student comprehension and achieving learning objectives (Shute et al., 2016). It provides educators with insights into student performance, highlighting strengths and areas for improvement.

To be effective, evaluation must be systematically integrated into the curriculum. It measures learning outcomes and examines the quality of inputs, processes, and results (Sadler, 2016). This comprehensive approach enhances education by motivating students, improving teaching methods, and encouraging institutional investments in better resources. Thus, evaluation is a key tool for driving continuous improvement and elevating the overall quality of education.

3.7. Application of Instructional Model

The table below summarizes each respondent's responses on applying instructional models in the science education course.

Table 8. Respondent's responses on application of instructional models

Respondent	Response
1	Diverse model with lectures and group project assignments for presentations
2	Varied model including games and project assignments
3	Diverse model incorporating lectures and project assignments
4	Varied model focusing on project assignments
5	Diverse model, not limited to lectures

This table highlights the diverse teaching models used in the course, incorporating lectures, project assignments, and interactive activities. Feedback from respondents indicates that the instructor has effectively combined traditional lectures with engaging tasks, such as projects and presentations, demonstrating a strong commitment to enhancing the learning experience and promoting active student engagement.

An effective instructional model fosters student involvement (Heilporn et al., 2021). Innovative instructional models can significantly enhance student activity and comprehension. Active participation reflects student enthusiasm during discussions, presentation attentiveness, and efficient task completion.

Key components of an effective instructional model include syntax, social systems, reaction principles, supporting systems, instructional impact, and feedback mechanisms (Darling-Hammond et al., 2020). By integrating these elements, educators can create a learning environment that increases student engagement and fosters more profound understanding.

3.8. Course Activities

Specifically, to gather information about classroom activities in the science education course, all respondents were asked several questions summarized in Table 9.

Table 9. Respondent's responses about classroom activities in the science education course

Question about	Summary of Responses
Activities encouraging participation and communication	• Group discussions, presentations, and Q&A make students more active. Games and prompts from lecturers help engagement.
Discussions in class	• Discussions improve critical thinking and curiosity. Group work and Q&A help students participate more.
Use of technology	• PowerPoint is only used, and no other technology or media is used.
Understanding science concepts	• Basic science concepts were introduced earlier. Projects like water rockets offer brief exposure to concepts
Knowledge of teaching models	• Limited knowledge of teaching models. No detailed explanation or repetition of models.
Creating lesson plans	• No experience creating science lesson plans. Not required to make lesson plans (RPP).
Creating teaching media or prototypes	• Some assignments to make prototypes (e.g., ecoprint), but explanations are unclear.
Encouraging creative thinking	• Projects (e.g., ecoprint, videos) encourage creativity. Some experience in making teaching media.
Supporting creativity development	• Creativity development is limited. Needs more varied activities and better use of technology.
Challenges faced in class	• More opportunities to create media needed. Some issues with time management during practice.

Based on the interview results, it was found that activities designed to encourage pre-service teachers in communication and discussion have successfully increased active classroom participation. This increased participation is evident through group discussions, presentations, and Q&A sessions, with these interactive methods proving effective in enhancing student engagement. Research indicates that activities involving direct interaction can help students become more active in the learning process, improve their understanding of the material, and encourage them to be more open in expressing opinions and exchanging ideas (Lilibeth & Natividad, 2023; Ullah & Anwar, 2020).

The use of technology in classroom activities is currently limited to PowerPoint, with no other supporting media. This indicates that the integration of technology in the learning process remains minimal. Lectures have not fully utilized technological tools to create a more interactive and varied learning experience. Furthermore, this limitation reflects a lack of effort to engage pre-service teachers in using and exploring technology in their learning process. Applying diverse technologies in the classroom could help meet the needs of various student learning styles, enrich the learning experience, and enhance engagement and understanding of the material (Tuma, 2021). Therefore, broader technology integration would improve instructional effectiveness and equip pre-service teachers with relevant technological skills to support their future teaching practices (Wilson et al., 2020).

In teacher education courses, the effective integration of technology encompasses a variety of tools and platforms. For example, interactive simulations such as PhET elucidate abstract scientific concepts, while gamification platforms like Quizizz enhance student engagement through interactive quizzes. Furthermore, augmented reality (AR) can present three-dimensional models. Pre-service teachers can

also receive training in collaborative tools like Google Workspace to facilitate group work within project-based learning settings. Additionally, Edpuzzle enables the creation of interactive video lessons that actively engage students in learning. Implementing Learning Management Systems (LMS) such as Google Classroom provides all participants with a structured and personalized learning experience. These strategies enrich the teaching and learning experience and equip pre-service teachers with essential technological competencies that are vital for their future educational practice.

Interviews with pre-service teachers reveal that while basic science concepts are introduced, this introduction is often brief and lacks depth. For example, projects like the water rocket can demonstrate physics principles such as pressure and gravity. However, without thorough exploration, they become mere technical tasks rather than opportunities for deep understanding.

Pre-service teachers commonly struggle with both fundamental science concepts and effective teaching methodologies. This gap limits their ability to create engaging lessons, as they often lack the pedagogical frameworks necessary for successful instruction. Additionally, teacher training programs frequently do not offer practical experience in designing interactive science lessons, which is vital for developing applicable knowledge in real classroom settings (Furtak & Penuel, 2019b).

While lecturers assign tasks aimed at fostering creative thinking skills, challenges remain. Many students report vague guidelines focusing more on task completion than exploring innovative ideas (Newman & DeCaro, 2019). This lack of clarity undermines the purpose of the assignments, which should cultivate creativity. To enhance the development of creative thinking skills, lecturers should provide clear instructions and consistent support, ensuring that pre-service teachers gain both the technical skills needed for the assignments and the creative abilities essential for their future as educators.

4. CONCLUSION

The findings indicate key improvements needed in the science education course to enhance learning and pre-service teachers' engagement. The lack of a formal syllabus and lesson plans may impair pre-service teachers' comprehension of course objectives and learning trajectories. While verbal guidance is provided, structured documentation would better support student planning. Additionally, reliance on limited teaching media, primarily PowerPoint and the whiteboard, underscores the need for a broader technological approach to accommodate diverse learning preferences. The absence of instructional tools, such as activity sheets, particularly in project-based contexts, restricts structured, hands-on learning and concept mastery.

The course also shows gaps in fostering creativity and essential teaching skills, such as lesson planning and prototype development. Expanding creative activities and integrating technology more effectively could enhance interactive, skill-based learning. Moreover, systematically applying varied assessment methods would offer valuable insights into pre-service teachers' progress and inform instructional refinements. In summary, enhancing course organization, incorporating diverse media, offering well-structured resources, and fostering an environment that supports creativity and skill development are crucial for promoting pre-service teachers' engagement motivation and achieving meaningful learning outcomes in the science education course.

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