

## STEM-BASED PHYSICS MODULES: A PRACTICAL APPROACH TO DEVELOPING CONCEPTUAL UNDERSTANDING IN TEACHER EDUCATION

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**Abstract:** STEM (Science, Technology, Engineering, and Mathematics) based learning approaches are increasingly recognized as an effective method in increasing understanding of physics concepts for prospective teachers. This research aims to evaluate the implementation of learning, lecturer responses, and student responses to STEM-based teaching modules in Basic Physics courses for prospective physics teachers at UIN Mataram. This research uses a quantitative research method with a descriptive design, which involves collecting data through learning accessibility observation sheets and questionnaires to measure lecturer and student responses to the implementation of the module. The research results show that the STEM-based teaching module in the Basic Physics course has proven to be practical in implementing basic physics learning, and has received positive responses from lecturers and students. Based on these findings, it is recommended that STEM-based teaching modules be further improved in the aspects of material visualization and time management to better support more effective learning.

**Keywords:** STEM, physics modules, conceptual understanding, teacher education

**Abstrak:** Pendekatan pembelajaran berbasis STEM (Science, Technology, Engineering, and Mathematics) semakin diakui sebagai salah satu metode yang efektif dalam meningkatkan pemahaman konsep fisika bagi calon guru. Penelitian ini bertujuan untuk mengevaluasi keterlaksanaan pembelajaran, respon dosen, dan respon mahasiswa terhadap modul ajar berbasis STEM pada mata kuliah Fisika Dasar bagi calon guru fisika di UIN Mataram. Penelitian ini menggunakan metode penelitian kuantitatif dengan desain deskriptif, yaitu pengumpulan data melalui lembar observasi aksesibilitas pembelajaran dan angket untuk mengukur respon dosen dan mahasiswa terhadap keterlaksanaan modul. Hasil penelitian menunjukkan bahwa modul ajar berbasis STEM pada mata kuliah Fisika Dasar terbukti praktis dalam melaksanakan pembelajaran fisika dasar, dan mendapat respon positif dari dosen dan mahasiswa. Berdasarkan temuan tersebut, direkomendasikan agar modul ajar berbasis STEM lebih ditingkatkan lagi pada aspek visualisasi materi dan manajemen waktu agar lebih mendukung pembelajaran yang lebih efektif.

**Kata Kunci:** STEM, modul fisika, pemahaman konseptual, pendidikan guru

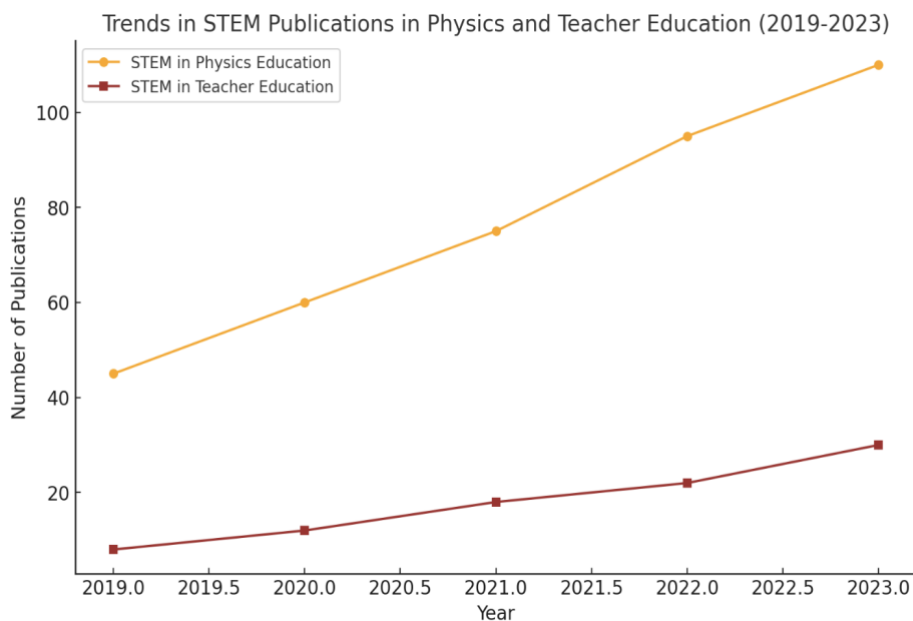
### INTRODUCTION

Science education currently faces big challenges in preparing prospective teachers who are able to master physics concepts in depth and apply them (Dare et al., 2021; Strat et al., 2024). A learning approach based on Science, Technology, Engineering, and Mathematics (STEM) is an innovative solution to improve understanding of physics concepts while developing 21st century skills such as critical thinking, problem solving, and collaboration (Hernandez-de-Menendez et al., 2020; Hwang & Lai, 2020; Martyniuk et al., 2021). In the context of teacher education, STEM not only functions as a learning approach, but also as a means to equip prospective teachers with

relevant pedagogical skills in the digital era (Samsudin et al., 2020; Rosales et al., 2020; Simeon et al., 2020). However, the implementation of STEM in physics learning modules in Indonesia is still limited, both in terms of the availability of practical teaching materials and their effectiveness (Sulaeman et al., 2022; Altmeyer et al., 2020). Therefore, it is important to develop STEM-based physics teaching modules that are practical and relevant for prospective teachers.

The results of the preliminary study show that many prospective physics teachers have difficulty understanding basic concepts such as Newton's laws, energy, and waves, especially when these concepts are related to real-world applications. This study was conducted through interviews and surveys of 30 prospective physics teachers at state universities in Indonesia. As a result, 76% of respondents felt that the teaching materials they had used so far did not support applicative mastery of concepts. Apart from that, they also find it difficult to integrate STEM approaches in learning because of the lack of practical guidance. This shows an urgent need for teaching materials that can help prospective teachers understand and teach physics concepts with a STEM approach.

Bibliometric analysis of international publications in the last five years also shows significant trends in the development of STEM-based teaching materials for physics education. Based on data taken from the Scopus and Google Scholar databases, there are more than 200 articles discussing the integration of STEM in physics learning. The majority of the articles highlight the effectiveness of STEM approaches in improving understanding of physics concepts and problem-solving skills. However, only about 15% of these articles specifically highlight STEM applications in teacher education. This fact confirms that there is a research gap in this field, especially regarding the development of practical and applicable teaching modules for prospective physics teachers.



**Figure 1.** Trends in STEM Publication in Physics and Teacher Education (2019-2023)

Figure 1 shows the publication trend related to the integration of STEM in physics education and teacher education from 2019 to 2023. STEM in Physics Education experiences a significant increase every year, with the number of publications continuing to increase, reaching 110 publications in 2023. STEM in Teacher Education also is increasing, but the number of publications is lower than in physics education in general, indicating a research gap in this field. This data confirms the importance of developing STEM-based research and teaching materials that are more focused on teacher education.

STEM-based teaching modules have great potential to improve the quality of physics learning at the teacher education level (Rasmi et al., 2023; Prasetyo et al., 2021; Utami et al., 2020). This module is designed to integrate physics concepts with technology, engineering and

mathematics, so that prospective teachers can understand concepts in a more contextual and relevant way (Irdawati et al., 2023; Othman et al., 2022). Apart from that, this module can also help prospective teachers to develop interactive and project-based learning methods, which are really needed in the Merdeka Belajar curriculum (Hendri et al., 2021; Ferdiani, 2022). The use of STEM-based modules not only improves understanding of concepts, but also provides meaningful learning experiences for prospective teachers, which will ultimately impact the quality of their teaching in the future (Hutomo et al., 2022).

In developing STEM-based teaching modules, practical aspects are the main factor that must be considered (Al Mamun et al., 2020; Huang et al., 2020). Practical modules are not only easy to use, but also flexible to apply in various learning contexts (Harefa & Hulu, 2024; Nerantzi, 2020). The practicality of this teaching module can be measured by its ease of use, the relevance of its content, and its ability to help prospective teachers master physics concepts (Aljawarneh, 2020). Based on the results of preliminary observations, prospective teachers prefer modules that include step-by-step guides, real application examples, and exercises that support critical thinking skills. Therefore, the design of STEM-based modules must take these needs into account to ensure their success.

The development of STEM-based teaching modules must also be supported by comprehensive research. One approach that can be used is a research and development (R&D) model which involves validation by experts and field trials. Validation by experts aims to ensure that the module meets quality standards in terms of content, presentation and relevance to the STEM approach. Meanwhile, field trials are needed to determine the effectiveness of the module in increasing prospective teachers' understanding of physics concepts. This process also involves evaluating the level of practicality of the module based on user experience.

Apart from that, implementing STEM-based teaching modules requires adequate technological support (Rasmi et al., 2023; Septiadevana & Abdullah, 2024). Technology can be used to enrich module content through interactive media such as videos, simulations and web-based applications (Mardiantiningsih et al., 2024). Previous studies show that the use of technology in teaching modules can significantly increase interest in learning and understanding of concepts (Pertiwi et al., 2024). Therefore, the development of this module must also consider the integration of technology to support more effective and interesting learning.

By integrating the results of preliminary studies and bibliometric analysis, this research aims to develop a practical and effective STEM-based physics teaching module for prospective teachers. It is hoped that this research can make a real contribution to the world of education, especially in improving the quality of physics learning at the teacher education level. Apart from that, it is also hoped that this module can become a reference for the development of other STEM-based teaching materials in Indonesia.

## METHOD

This research is a continuation of the validation of STEM-based teaching modules that have been carried out previously. The focus of this research is to test the practicality of the module to improve prospective teachers' understanding of physics concepts. The research subjects were 30 prospective physics teachers at UIN Mataram who took the Basic Physics course, consisting of 10 men and 20 women, as well as one lecturer teaching the course who used teaching modules in the learning process. Data collection instruments include learning implementation observation sheets to assess the extent to which modules are used effectively in class as well as questionnaires to determine the responses of lecturers and prospective teachers to the use of modules. Below is a grid of the instruments used in this research.

Data analysis was carried out qualitatively and quantitatively, where qualitative data was obtained from participants' qualitative responses regarding the module, while quantitative data was obtained from implementation observations which were analyzed in the form of percentages of achievement.

**Table 1. Research Instrument Grid**

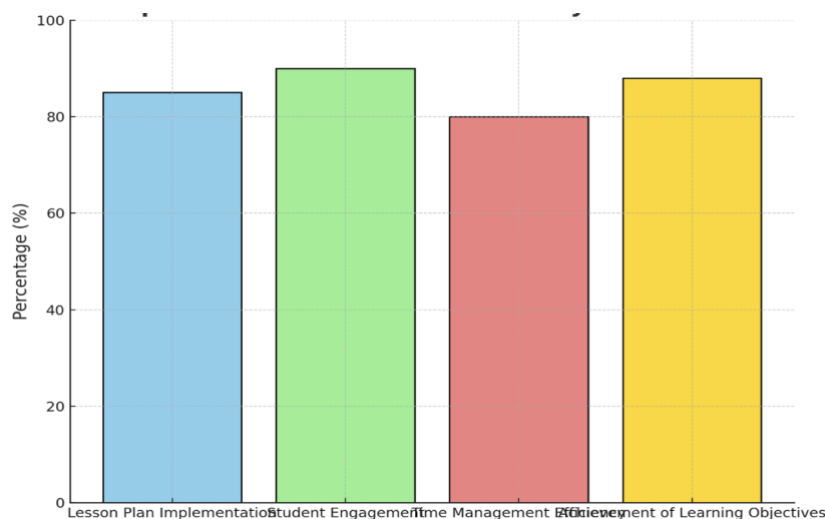
Rated aspect	Indicator	Instrument Type	Scale/Format
Implementation of Learning	Lesson plan implementation	Observation Sheet	Scale 1-5
	Student engagement	Observation Sheet	Scale 1-5
	Time management efficiency	Observation Sheet	Scale 1-5
	Achievement of learning objectives	Observation Sheet	Scale 1-4
Lecturer Response	Content Suitability	Response Questionnaire	Likert scale 1-5
	Relevance to Learning Objectives	Response Questionnaire	Likert scale 1-5
	Clarity of Material Presentation	Response Questionnaire	Likert scale 1-5
	Visual Design and Layout	Response Questionnaire	Likert scale 1-5
	Alignment with STEM Approach	Response Questionnaire	Likert scale 1-5
	Support for Conceptual Understanding	Response Questionnaire	Likert scale 1-5
Prospective Teacher Response	Content Suitability	Response Questionnaire	Likert scale 1-5
	Clarity of Presentation	Response Questionnaire	Likert scale 1-5
	Relevance to Learning Objectives	Response Questionnaire	Likert scale 1-5
	Visual Design and Layout	Response Questionnaire	Likert scale 1-5
	Support for Conceptual Understanding	Response Questionnaire	Likert scale 1-5

## RESULT AND DISCUSSION

In this section, the results and discussion of the research are explained in detail regarding the implementation of STEM-based teaching modules in Basic Physics courses for prospective physics teachers at UIN Mataram. This research aims to evaluate the implementation of learning, lecturer responses, and student responses to the teaching module. To achieve this goal, data was collected through observation sheets and questionnaires given to lecturers and students, which measured various important aspects of the learning process, including the effectiveness of the use of teaching modules and the level of student involvement.

The results obtained are discussed by linking the findings obtained with relevant learning theories, especially those that focus on STEM-based approaches. Apart from that, this discussion also links the research results with previous research findings to provide a clearer picture of the contribution and potential of STEM-based teaching modules in improving the quality of physics learning for prospective teachers. In this section, an in-depth analysis of the implementation of learning, lecturer responses, and student responses regarding the effectiveness and impact of implementing this approach is presented. Below are presented the results of learning implementation using the teaching modules developed.

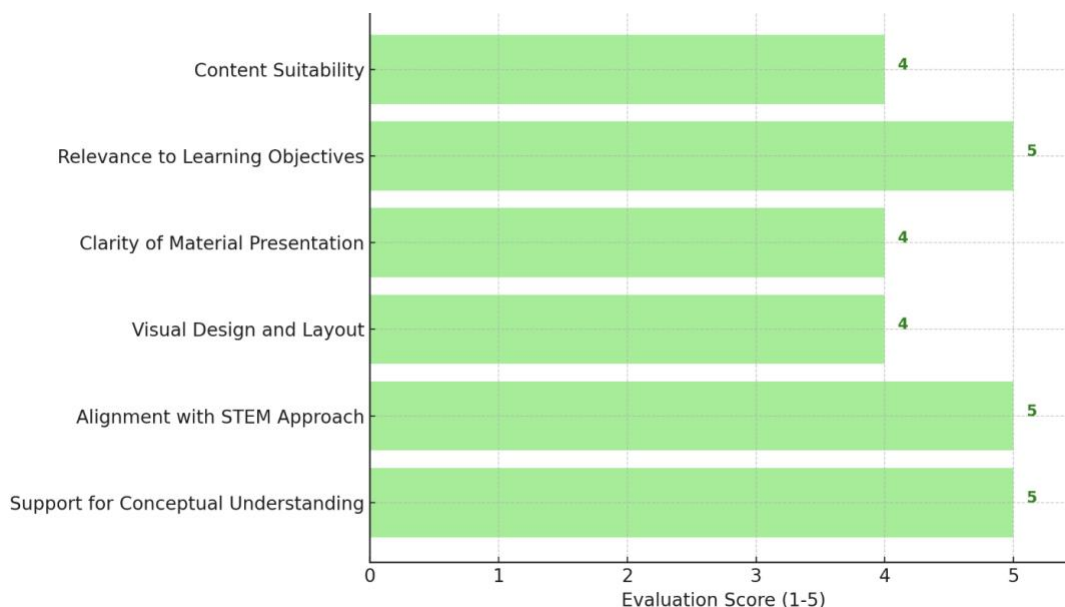
The implementation of learning with STEM-based physics modules shows very good results, with indicators Lesson Plan Implementation reaches 85%, Student Engagement by 90%, Time Management Efficiency reaches 80%, and Achievement of Learning Objectives by 88%. These results reflect that a STEM-based learning approach is able to integrate active student involvement and efficient implementation of learning activities.



**Figure 2.** Implementation of Learning

These findings are in line with previous research by Hacıoğlu & Gülhan (2021), which states that the STEM approach helps develop critical thinking skills and improve students' understanding of concepts through structured and applied learning. In addition, according to research by Ardianti et al (2020), the integration of STEM in teacher education not only increases the effectiveness of lesson planning but also leads students to better understand the relationship between theory and practice.

However, it should be noted that the time management efficiency (80%) shows room for improvement, which may be related to the need for adaptation in the implementation of new modules. Previous research by Simeon et al (2020) also shows that STEM learning requires longer adaptation time than conventional methods, especially when involving project-based activities. Below are also presented the results of the responses of lecturers teaching basic physics courses related to the teaching modules developed.



**Figure 3.** Instructor Response to STEM-Based Teaching Module

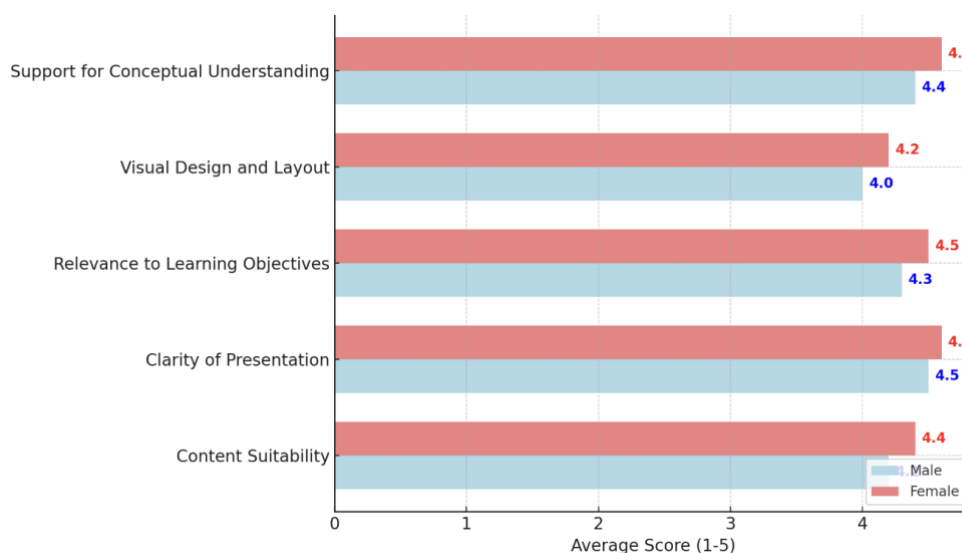
The graph above shows the response of one lecturer teaching Basic Physics courses to the STEM-based teaching module that was developed. Assessments were carried out on six main aspects: Content Suitability, Relevance to Learning Objectives, Clarity of Material Presentation, Visual Design and Layout, Alignment with STEM Approach, and Support for Conceptual Understanding.

The evaluation results show a fairly high score ranging from 4 to 5, which reflects that the module is considered positive and relevant as a basic physics learning medium. This assessment is in line with the findings of Astuti et al. (2016) who emphasized that the STEM approach is effective in facilitating concept-based learning and triggering students' deep understanding.

Aspek Relevance to Learning Objectives, Alignment with STEM Approach, and Support for Conceptual Understanding received the highest score, namely 5, indicating that the teaching module developed is considered very appropriate to the specified learning outcomes. This supports research by Reynders et al (2020) and Baran et al (2021) which states that STEM-based modules are able to provide links between science, technology, engineering and mathematics concepts in an integrated manner, thereby strengthening the relevance of the material to the competencies to be achieved. Apart from that, this approach is considered capable of improving students' critical thinking abilities and problem-solving skills.

On the other hand, the Content Suitability aspect, Clarity of Material Presentation, And Visual Design and Layout received a score of 4, which means that even though the module is considered good, there is still room for improvement, especially in the visual appearance and presentation of the material to make it more interesting and easier to understand. This finding is in line with research by Lasekan et al (2024) which revealed that visual design and clarity of presentation in teaching modules play an important role in maximizing student engagement and learning effectiveness. Systematic presentation of material and attractive visuals can help prospective teachers understand basic physics concepts more easily.

Overall, positive responses from lecturers indicate that STEM-based teaching modules have great potential to support the basic physics learning process. Previous research by Bunyamin et al (2020) also confirmed that the integration of STEM in teacher education can help prospective educators develop a more comprehensive and applicable understanding of physics concepts. With slight improvements to the visual and presentation aspects, this module can be a more optimal instrument for increasing students' conceptual understanding in basic physics education. Below are also presented the results of prospective teacher responses related to the learning and teaching modules developed.



**Figure 4.** Responses of prospective teachers

The graph above depicts the responses of 30 prospective physics teachers taking Basic Physics courses at UIN Mataram, consisting of 10 male participants and 20 female participants. Assessments are carried out on five main aspects: Content Suitability, Clarity of Presentation, Relevance to Learning Objectives, Visual Design and Layout, as well as Support for Conceptual

Understanding. The results show that female teacher candidates gave slightly higher average scores than male teacher candidates in all aspects.

The Relevance to Learning Objectives and Support for Conceptual Understanding aspects received the highest scores from both male (4.3 and 4.4) and female (4.5 and 4.6) participants. This shows that the modules and materials in the Basic Physics course are considered very relevant to learning outcomes and effective in helping prospective teachers understand physics concepts. These results support the research Hamad et al. (2022) which confirms that the STEM approach in science learning is able to provide strong material relevance to educational goals and increase students' in-depth understanding of basic concepts.

On the other hand, the Visual Design and Layout aspect received a lower score than other aspects, with a score of 4.0 from male participants and 4.2 from female participants. This indicates that although the visuals and layout of the module are considered good, there is room for improvement to make it more attractive and easy to understand. Study Hanif (2020) & Winarto et al. (2020) revealed that effective visual design in teaching materials plays an important role in increasing students' interest in learning and conceptual understanding. Therefore, improvements in the visual aspect support the overall effectiveness of the module.

In general, the small differences in scores between male and female participants indicate positive consistency regarding the quality of the Basic Physics course. Previous research by Aldemir et al (2022) states that a STEM-based approach is able to provide a more integrated learning experience, for both male and female participants, in connecting physics concepts with real life. Thus, the results of this evaluation show that the Basic Physics course at UIN Mataram is running well and is relevant, although the visual aspects and presentation of the material can still be improved to achieve more optimal results.

In general, the results of this research show that the implementation of STEM-based teaching modules in Basic Physics courses is going well and effectively. This module is able to facilitate the implementation of learning that is more structured and relevant to the learning objectives. With an integrative approach that combines theory and practice, students demonstrate active involvement in the learning process, which has a positive impact on their understanding of basic physics concepts. This indicates that the STEM method is successful in creating a more contextual and meaningful learning environment for prospective teachers. This research is in line with the findings Nguyen et al. (2020) which states that the STEM approach helps students not only master the material but also connect it with real applications in everyday life.

The lecturer's response to the teaching module also showed good acceptance, where the material prepared was assessed in accordance with learning needs and course objectives. Using a STEM approach allows lecturers to manage learning more systematically and interactively. This supports the view that STEM-based teaching modules not only help students understand the material, but also make it easier for teachers to convey complex concepts in a simpler and more applicable way. These findings strengthen the research results Hiğde & Aktamış (2022), which emphasizes the importance of a STEM-based approach to support lecturer involvement in delivering more practical and relevant learning.

On the other hand, the positive response from prospective teachers shows that this module provides an enjoyable and useful learning experience for them as future educators. This module successfully bridges the gap between theory and its application in real life, and encourages prospective teachers to think critically and creatively. Although there are still several aspects that need to be improved, such as time efficiency and material visualization, these results strengthen the evidence that the STEM approach is an effective strategy in developing the competencies of prospective physics teachers. Previous research by Okundaye et al. (2022) also shows that the STEM approach is able to create more meaningful and in-depth learning experiences for students, improving their abilities in critical thinking and problem solving.

The results of this research are in line with theory constructivism in learning, which emphasizes that knowledge is built through direct experience and active interaction with the learning environment. The STEM approach, as an implementation of this theory, encourages

students to connect physics concepts with real situations, so that learning becomes more meaningful and relevant. According to Piaget and Vygotsky, effective learning occurs when students are involved in activities that challenge their thinking, work collaboratively, and solve problems independently or in groups. STEM-based teaching modules provide space for students to explore concepts, experiment, and analyze problems with an interdisciplinary approach, thereby not only increasing understanding of concepts, but also critical thinking and problem solving skills that are much needed in the world of modern education.

Overall, this research strengthens the evidence that a STEM-based approach can improve the quality of learning, both in terms of student engagement, understanding of concepts, and lecturers' time management abilities. With modules designed to be interactive and applicable, learning becomes more interesting and relevant to the needs of today's world of education. This research contributes to the development of STEM-based teaching materials, as well as supporting the development of prospective teacher competencies to face increasingly complex educational challenges in the future. In the future, visual aspects, time management and more effective use of technology need to be optimized so that this teaching module can have a maximum impact on prospective teachers.

## CONCLUSION

The conclusion of this research shows that the STEM-based teaching module in the Basic Physics course has proven to be practical in implementing basic physics learning, and has received a positive response from lecturers and students. This approach not only helps students to understand physics theory in depth, but also connects it with practical applications that are relevant to everyday life. Positive responses from lecturers and students confirm that this module can increase active student involvement, support more effective learning management, and encourage the development of critical and creative thinking skills. Thus, STEM-based modules are a strategy that has great potential in developing the competencies of prospective teachers, which needs to continue to be refined to increase their effectiveness in the future.

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