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Need Analysis of STEM-ESD Based Development on Teaching Materials and Instrument Test

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Abstract: This study aims to determine the need for developing STEM-ESD-based teaching materials as a learning resource for students in physics subjects in high school. This research uses mixed methods, which consisted of qualitative data and quantitative data. This research involved 26 respondents spread across several schools in Majalengka The instruments used are 17 questionnaires, namely 8 questions to identify difficulties in solving physics problems, 7 questions about student responses to the teaching materials used and 2 questions about causal factors and expected textbooks. Based on the preliminary study conducted, it is known that the teaching materials used so far have not met the indicators of good teaching materials, students have difficulty solving physics problems with a percentage of 73%, the student responses to the teaching materials used with a percentage of 81%, so require STEM-ESD-based teaching materials as a resource study. The results of the preliminary study also see that the teaching materials developed later can measure critical thinking and problem-solving skills. Based on this, the use of teaching materials as a learning resource is needed by students, so it is necessary to conduct a needs analysis in the development of STEM-ESD-based teaching materials.

Keywords: Development teaching materials; ESD; STEM

Introduction

The results of the 2015 Program for International Student Assessment (PISA) study show that the scientific ability of Indonesian students is still low (Rahmayani et al., 2019; Zhasda et al., 2018). In the 2015 PISA results report, the average science score for Indonesian students is 403 (Jufrida et al., 2019; Susongko et al., 2018). They are ranked 62 out of 69 PISA participating countries (Auld et al., 2019; Robertson, 2021). The low achievement results can be seen in the results of The Trend in the International Mathematics and Science Study (TIMSS) in 2011 in the fields of mathematics and science (Liouaeddine et al., 2018; Wendt et al., 2016). The low quality of student learning outcomes shows that the learning process carried out by the teacher is still teacher centered, so that the teacher becomes the only source of learning for students (Marshel et al., 2020; Putra et al., 2021; Suhirman et al., 2023). Teachers use the lecture method more in learning, and do not associate learning (Ichsan et al., 2023; Lestari et al., 2021) with problems in the real life of students every day (Syukri et al., 2021). The learning carried out did not train students' skills (Hadi et al., 2018). There are significant educational challenges as many US states are transitioning their science standards to align with the Next Generation Science Standards (Hayes et al., 2016). The 21st -century brought about major changes in the relationship between technological developments and the world of education so that the relationship between the two became faster (Tytler, 2020). Along with the complex problems in classroom learning activities, students' competencies are not limited to process abilities but need to have 21st century skills (Artika et al., 2023).

The 21st century skills known as 4C Ability include critical thinking and problem-solving, creativity and innovation, communication, and collaboration (Susilo et al., 2020). In facing the development of science and

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technology, the best facilities are needed so that learning can achieve educational goals (Kingsley, 2017), so that education can produce graduates who are competent in global competition (Sjøen, 2023). To support 21st century capabilities, there are several approaches that we can use, one of which is STEM (Science, Technology, Engineering, and Mathematics) as an approach. Currently, many teaching materials in the form of Physics books are available (Amalya et al., 2021; Widayanti et al., 2019). However, most Physics books are still centered on material content and are not contextual in studying various phenomena around them. The 2013 curriculum is a strategic step for the government to realize the challenges of the 21st century (Setiawan, 2020). The rapid advances in technology today have both positive and negative impacts (Manalu et al., 2022). To minimize the negative impact of the development of technology, education should be prepared as a provision for sustainable development (Asrizal et al., 2023). This issue, as proclaimed by UNESCO (Ahel et al., 2020), namely Education for Sustainable Development (ESD) or education for sustainable development.

This is in accordance with what was instructed by UNESCO (Ahel et al., 2020) that ESD must be integrated in curriculum and textbooks or teaching materials in formal education, which consists of early childhood education (Martín et al., 2020), primary and secondary education (Wang et al., 2021), vocational technical education and training, and higher education. Based on the results of the literature study, information was obtained that the teaching materials used so far have not integrated the objectives of STEM-ESD and the problems that exist in the teaching materials so far are still routine contextual problems (Fathurohman et al., 2023). Through this analysis of the needs of teaching materials, it is hoped that this can be the first step in the need for a product of physics teaching materials that can overcome the problem of the less-than-optimal ability of critical thinking and problem solving of students.

STEM Education

STEM learning is an integration of learning science, technology, engineering, and mathematics which is suggested to help the success of the 21st century (Yuenyong et al., 2021). STEM-based Education Skills can form human resources (HR). Able to reason and think critically, logically, and systematically, so as to be able to face global challenges and be able to improve the country's economy. STEM can develop when associated with the environment, so that there is learning that presents the real world experienced by students in everyday life (N. Putri et al., 2019). This means that through the STEM approach students do not just memorize concepts, but how students understand and understand scientific concepts and their relationships in everyday life. Based on this explanation, learning using STEM is an important question, because it provides training to students to be able to integrate each and every aspect. These aspects are called science, technology, engineering, and mathematics (M. A. N. Putri et al., 2022). STEM in the process of learning Physics is expected to equip students with various skills needed by students in the 21st century. Integrated STEM learning is an effort to combine science, technology, engineering, and mathematics into one class that is based on the relationship between subjects and real-world problems (Belland et al., 2017).

STEM was introduced in 1990 by Mark Sanders. Initially the term used was "SMET" which stands for Science, Mathematics, Engineering, and Technology. However, one NSF office worker (National Science Foundation) complained about the pronunciation of "SMET" which sounded like "smut" so that the acronym "STEM" was born (Holt, 2012; Syahmani et al., 2021). The purpose of implementing STEM learning is to create staff who have competence in the fields of science, technology, engineering and mathematics which are included in fields that are considered promising fields for getting better jobs (Setyaningsih et al., 2022). These four areas are stated as the key to success in the country's development in the 21st century (Listiaji et al., 2022). STEM learning is considered capable of creating an intelligent workforce to think critically, think logically and systematically (M. A. N. Putri et al., 2022). If the application of STEM can be implemented, it will produce graduates who are able to face challenges globally and are able to improve the economy in a country (Sholahuddin et al., 2022; Wu et al., 2016). The STEM discipline has been described by the National Academy of Engineering and National Research in 2009 in Katehi, Pearson, & Feder including:

Science, is the discussion of nature, including natural laws related to physics, chemistry and biology, as well as the application of facts, concepts, principles and practices related to these teachings. Science is a body of knowledge accumulated over time through scientific research to create new knowledge that informs the engineering design process; Technology, is not a strict discipline, this discussion includes systems, processes, knowledge, and equipment systems of all people and organizations that are used to create and service technological objects as well as the objects themselves. Throughout history, humans have developed technology to meet their needs and wants. Most modern technologies are products of science, engineering and technical equipment are used in both fields; Engineering, discussing the design and creation of products made by humans and the process of solving problems. This process is designed under constraints. One of the limitations in engineering design is the laws

of nature or science. Other constraints included in engineering design include cost, time, available materials, agronomy, environmental regulations, productivity and repair ability. The discussion of this technique uses the concept of science and mathematics; Mathematics, discussion of patterns of relationships between numbers and shapes. Special branches in mathematics include arithmetic, geometry, algebra, trigonometry and calculus. Mathematics is used in discussions of science, engineering and technology. The results of the study (Dou, 2019) say that STEM in the context of literacy has the goal of:

Develop students' abilities to acquire knowledge, attitudes and problem-solving skills in different life situations, explain natural phenomena that occur, and draw conclusions from STEM; Understand the characteristics of STEM disciplines such as inquiry, knowledge forms, and human-initiated design; Creating an intellectual, material and cultural environment and as a caring citizen; and constructive and reflective personal participation (eg, limited resources, energy efficiency, and environmental quality) to have a desire to be involved in STEM-related scientific research. There are three approaches to STEM learning that can be developed according to Shekhar et al. (2014), including:

The silo approach, which is an approach that provides opportunities for students to gain knowledge rather than technical skills. The characteristics of the silo approach are that learning is still authoritarian for educators, students do not get many opportunities to actively participate in learning. This approach emphasizes knowledge so that it can be assessed; Embedded approach, namely an approach that emphasizes mastery of knowledge in the real world as well as problem-solving methods in the social, cultural and functional fields. The embedded approach emphasizes material integrity and connects the main material to the backing or embedded materials; An integrated approach, namely an approach that combines different STEM fields and does it in one subject. The integrative approach combines subjects including critical thinking skills, problem solving by integrating learning materials in the classroom. In line with the STEM application aims to develop students' skills by combining several scientific fields. Students will be more active in participating in learning that is they can develop the skills they have.

Gogia et al. (2018) proposes that the development of educational science begins to consider STEM learning as an important way to address the challenges and demands of this century. This starts from the idea that an individual must have the competence to understand STEM related to global issues; scientific recognition from other non-scientific explanations; propose a reasonable idea based on relevant evidence; fulfill responsibilities at local, national and global levels. There are several aspects in the STEM-based learning process according to Priemer et al. (2020), namely: Asking questions (science) and defining problems (engineering); developing and using models; planning and conducting investigations; analyzing and interpreting the data (mathematics); using mathematics; information and computer technology; computational thinking; build explanation (science) and designing a solution (engineering); engage in evidence-based arguments; obtain, evaluate, and communicate information.

In the development of STEM-based textbooks, it will be paired with the PjBL model starting from reflection, research, discovery, application, and communication because STEM is just an approach, not a learning model (Mujiono et al., 2021), so it is hoped that it can improve critical thinking and problem-solving skills. Several findings also state the results of the effectiveness of implementing PjBL in learning activities on students' critical thinking skills (Aqlan et al., 2022). Based on the characteristics of PjBL, it is not surprising that PjBL is suitable to be paired with STEM. As with the findings of (Kinley et al., 2021). PJBL STEM compatibility because they are the same equally challenging and motivating learners (Kaur et al., 2020; Mardiani et al., 2023). This makes students feel motivated to be active in conducting investigations and finding solutions to problems during learning activities to foster critical and creative thinking skills.

Education Sustainable for Development (ESD)

Education for Sustainable Development (ESD) was first proclaimed by the United Nations in 2005 which is a comprehensive paradigm in all aspects of life. The concept of sustainable development is based on development that meets the needs of the present, but does not reduce the ability of the next generation to meet their own needs (Giangrande et al., 2019). ESD can be defined as education that empowers humans to try to understand and solve problems that threaten life on earth. ESD integrates the principles of sustainable development in all aspects of education and learning (Atack, 2021). ESD is an effort to provide education and knowledge so that students can take advantage of nature while preserving it. ESD is designed to realize a holistic personality, a love for the environment that people feel and apply in an environmentally friendly life every day (Hsiao et al., 2021). Education for Sustainable Development is expected to change the paradigm and behavior of the whole community to participate in its implementation. The four pillars of sustainable development include building economic resilience that is just and sustainable, and preserving the environment and society to preserve cultural diversity (Hsiao et al., 2021). Developments that are taking place in various

countries are now experiencing rapid progress in various fields (Willats et al., 2018). However, many disasters occur in the environment such as floods, droughts, environmental pollution, landslides and even forest fires, which not only cause substantial losses but also deaths. The international community has agreed on the importance of protecting the planet from pollution and destruction through education on sustainable development (Lambini et al., 2021). This development is a commitment and responsibility of the global community to save the earth from destruction due to development that does not pay attention to environmental sustainability. Sustainable development is used to facilitate the transition towards sustainability in order to understand the interaction between humans and the environment in which they live. The importance of sustainable development lies in meeting human needs while preserving other life on Earth (Misiaszek, 2022). ESD is an attempt to offer humanity insight into the uses of nature, with an emphasis on sustainability.

ESD is designed to be known by the whole community to build characters that are environmentally friendly, love the environment, and easily adapt to everyday life. The presence of ESD enables society to develop environmental and social resilience in four pillars, namely a just and sustainable economy and the preservation of the country's cultural diversity (Pimdee, 2021). Indonesia has also responded positively to the 10 year discourse ESD. The Ministry of Education views education for sustainable development as a paradigm that makes human beings with noble morals a blessing to the universe (Haryono, 2020). This enables humans to meet their own needs, taking into account the needs of present and future generations. This sustainable development paradigm invites people to think about the planet and its sustainability (Zejnilovic et al., 2023). Education is expected to develop an understanding of the importance of ecological balance and social responsibility for nature which enables students to work synergistically with other people and with all natural systems. Thus, a critical awareness of the environment (social and natural) emerges and various interventions for the better environment (Guo et al., 2022).

Method

The participants were grade XI MIPA students in one of the SMAN in Majalengka which can be seen in Figure 1 (with regional boundaries marked with red lines).

Figure 1. Location research in Majalengka

This study used a mixed-method (Creswell, 2004), consisting of qualitative data and quantitative data. The sampling technique was conducted by purposive sampling. Data collection was done by giving questionnaires to students. The questionnaire was given to 26 students (18 eneng and 8 aa), for each question students used a four-point Likert scale (Reardon et al., 2017). Respondent was asked to state the following Table 1.

Table 1. Likert Scale Four-Point

Statement	Information
SA	Strongly Agree
A	Agree
D	Disagree
SD	Strongly Disagree

The questionnaire contains 15 questionnaires, namely 8 questions to identify difficulties in solving physics problems, 7 questions about student responses to the need teaching materials. Qualitatively 2 questions about causal factors and expected textbooks; the data and information obtained during the research study are analyzed and then interpreted.

Result and Discussion

Analysis response of the students toward difficulty in physic lesson consists of eight questions which the students were asked to choose one answer from the question that was given to them. The statements about the difficulty in the physic lesson are presented in table 2.

Table 2 presents P1-P3 statements are meant to know the preference for the physic lesson. The data that was obtained about 62.5 % of students dislike physic lesson, but some students consider physics lessons to be very useful for life with a percentage of 50%, and students cannot solve problems in real life by studying physics by 68.8%. The P4-P8 statement is purposed to recognize the students' responses regarding the difficult subject. The data that are obtained supposed that most of the students believed difficulty during the physic

lesson because they must be challenged with equation and formula, experiment and testing, conceptual explanation at the same time. It is proved with the 73,8% percentage. This finding is maintained with the research by Sharpe et al. (2020) that assumed there are three students' difficulties in getting the concept of physic, namely; there is misunderstanding from the students in knowing the phenomena during resolving the problem, misread or ma misinterpret from the question that asked, and the students' mathematic skills that are still low. So when using STEM-based teaching materials, students will be trained in Science, Technology, Engineering and Mathematics. In addition, students will be more aware of sustainable living with the ESD approach in teaching materials.

Table 2. The Students' Statements about the Difficulty in Learning Physic

No.	Questions
P1	I like physics lessons
P2	I think physics lessons are very useful in life
P3	I can solve problems in life by studying physics
P4	I think that physics is difficult and boring
P5	I have difficulty solving physics problems
P6	I have difficulty using equations or formulas on physics problems
P7	I have trouble analyzing graphs and pictures
P8	I have difficulty concluding the material being studied

Analysis response of the student responses to the teaching materials used of seven questions. Those questions are presented in Table 3.

Table 3 presents student responses to learning resources used by teachers during the learning process. In P9 questions, 37.5% of students used textbooks, LKS; on P10 questions, 56.3% of students stated that the teaching materials used were not interactive; on P11 questions, 56.3% of students stated that the teaching materials used did not train critical thinking; on P12 questions, 50% of students stated that the teaching materials used did not practice problem solving; in question P13, 62.5% of students stated that project-based teaching materials would be more interesting; in question P14, 53.6% of students stated that the teaching materials used were not experimenting or making projects; on question P15 there are 50% of students stating that the teaching materials used cannot make students solve problems. This is supported by Widayanti et al. (2019) which says that the application of the STEM-based teaching material process with the existence of projects in learning so that it is needed by students.

Table 3. The Students' Response to the Teaching Materials Used

No.	Questions
P9	The learning materials used by the teacher during the learning process are textbooks, LKS
P10	The learning materials I use are very interactive during physics lessons
P11	The learning resources that I use to practice critical thinking skills
P12	The learning resources I use practice problem solving skills
P13	Learning physics will be interesting if you use project-based teaching materials.
P14	Physics textbooks used today do not provide a meaningful learning experience (experiments, project creation)
P15	Physics textbooks that are used today are not able to make me able to solve problems

The students' analysis response about causal factors and expected textbooks toward the need for interactive learning source has four statements. Those statements are presented in Table 4.

Table 4. The Students' Response about Causal Factors and Expected Textbooks

No.	Questions
P16	In your opinion, what are the factors causing the difficulties and problems experienced by using the teaching materials used?
P17	What kind of teaching materials do you want to overcome your difficulties and problems in studying physics?

Table 4 presents the constraints and desired learning resources as an alternative in learning. Question P16 is intended to find out the factors causing the difficulties experienced while using the teaching materials used, here are some of the students' answers:
S1: Don't understand
S2: It's boring especially all this time online
S3: the teacher rarely comes to class
S4: Some of the material in the book is explained in as much detail as possible, but it is long-winded and does not go straight to the part that must be understood.
S5: Learning online so I don't really understand
S6: Lack of interactive learning tools so that the left brain is often used and the right brain is not
S7: Sometimes just to read and understand from textbooks or worksheets, I feel like I don't understand
S8: Do not understand the formula, how to use the formula
S9: Because I'm lazy
S10: sometimes it doesn't explain the material in detail and it's a bit difficult to memorize formulas
S11: Many formulas

S12: because the teaching material is in the form of a book, it explains it in a dense and long way, so it is a little difficult to understand it
S13: the way the teacher explains it and the teacher rarely gives the material
S14: teachers and teaching materials used are less effective
Question P17 is intended to find out the desired teaching materials to overcome difficulties and problems in learning physics, here are some of the students' answers:
S1: Through that experiment, it will be easier to understand
S2: Short and clear explanation
S3: Provided examples and parables in everyday life so that I know what the physics formula is useful in.
S4: What was explained first was given an example
S5: Interactive teaching materials
S6: The one with lots of pictures and experiments
S7: Want to be explained and immediately put into practice
S8: Teaching materials with visual explanations such as videos and pictures
S9: The one with lots of experimental activities
S10: If you explain, let alone the experiment, it's really fun, so you understand
S11: learn as much as possible, you can use viewing media so you don't get too stressed
S12: Detailed teaching materials but not too long
S13: The teaching materials I want are in the form of files, pdf, and worksheets to make them more concise and easy to understand.
S14: making experiments, project creation, and other practices.

Conclusion

Based on the data from the needs analysis carried out, it can be seen that the development of STEM-ESD-based interactive teaching materials needs to be done. The conclusion is that students still have difficulty in solving physics problems, students need learning materials that can help solve physics problems. The contributing factor is that textbooks are difficult for students to understand and rarely conduct experiments, so students hope that the upcoming textbooks are textbooks that make students happy, easy to understand and practice critical thinking skills and solve physics problems. So, it is very necessary to develop teaching materials that are able to train these abilities, namely with STEM-based teaching materials with an ESD approach.

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PAS as the first author contributed to finding ideas, conducting research, writing research articles, collecting, processing, analyzing data, and writing articles. IK, AS, and RR as the second third and fourth author contributed to directed and guided the first author.

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The authors declare no conflict of interest.

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