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Need Analysis for Development of Inquiry-Based STEM Materials to Improve Critical Thinking Skills

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Abstract: 21st-century learning plays an important role in producing quality human resources. One of the skills that students must have to face this century is critical thinking skills. This research aims to determine students' critical thinking skills and find out to what extent the stages of inquiry learning have been implemented, as well as their integration with the STEM approach. The type of research used is survey research. The instruments used were interview guide sheets, tests of student critical thinking skills, observation sheets of learning implementation, and analysis sheets of the interviews conducted with 4 physics teachers in the four schools. The research results show that learning in schools is still conventional (teacher-centered). The integration of the inquiry process with the STEM approach in learning and the teaching materials used is still low. Students' critical thinking skills are also low. Therefore, the recommendation from this preliminary study is that there is a need to develop physics teaching materials that integrate inquiry learning with a STEM approach to improve students' critical thinking skills.

Keywords: Critical Thinking; Inquiry; STEM

Introduction

The spread of technology in the twenty-first century is comparable to the Industrial Revolution 4.0 (Desnita et al., 2022). 21st-century skills are standard skills that are widely agreed that students must have to meet the demands of future success in careers and life (Asrizal et al., 2022). The P21 framework classifies 21st-century skills into three main categories: a) learning and living; b) education and innovation; and c) information, media, and technology. The P21 work schedule further defines these basic categories. In the learning and innovation category, there are four types of 21st-century learning: creativity, critical thinking, communication, and collaboration (Novitra et al., 2021; R. Kelley et al., 2019).

The school curriculum must support and develop individual character who becomes the subject and object of education for learning that can accommodate 21st-century skills (Pike et al., 2021). Integrative curriculum has a close relationship with 21st-century learning (Khoiriyah et al., 2023). An educator's knowledge, skills, and dedication will influence how well they provide education in school (Shin, 2022). One of the demands of the school curriculum is learning physics. Schools are currently trying to teach physics to students not only to provide basic knowledge of physics but also to build ways of thinking that include creativity, critical thinking, problem-solving, decision-making, and how to work including communication and collaboration (Wibowo, 2023).

Critical thinking skills are one of the skills that are agreed to be the main important skills (Hidayah et al., 2020). This has been recognized by researchers, teachers, entrepreneurs, and public policymakers around the world. They have placed improving critical thinking

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skills as a top priority in education and society (Ahern et al., 2019; Pasquinelli et al., 2021). The critical thinking process consists of several sub-skills such as analyzing, evaluating, inference, interpretation, evaluation, and self-regulation which are used to increase logic to determine possible arguments or solutions (Davies & Barnett, 2015; Wulandari et al., 2021).

Improving students' critical thinking skills can be achieved by involving students in learning experiences that develop their critical thinking skills (Vieira & Tenreiro-Vieira, 2016). This is because critical thinking is related to mental processes such as predicting, analyzing, synthesizing, evaluating, and reasoning which can be improved through an inquiry-based learning process(Tiruneh et al., 2017). In general, inquiry learning shows student participation in thought processes and activities similar to a scientist conducting an investigation. Students are given meaningful experiences while learning to develop critical thinking skills as one of the skills needed in this modern era (Zhai, 2019). The implementation of inquiry learning consists of a series of stages or phases which are then arranged so that students can master the competencies that must be achieved by playing an active role in learning (Arini & Sulistyo Saputro, 2017). The stages of inquiry learning consist of orientation, conceptualization, investigation, conclusion, and discussion. Each stage provides an opportunity for each student to improve their thinking skills (Pedaste & Mitt, 2020; Salyani et al., 2020).

Inquiry learning is the process of investigating a problem, through the process of critical thinking and analysis to search for and find answers to a problem. This statement shows that the application of inquiry learning requires integration with an approach that can connect the field of study with problems in everyday life (Malasari et al., 2020). This is so that the learning carried out is more meaningful and can build a good understanding of concepts and foster students' critical thinking skills (Smallhorn et al., 2015). One way to present everyday life problems in learning is by using a STEM approach.

STEM education combines four STEM elements, namely science, technology, engineering, and mathematics to solve everyday problems (Zakiyah et al., 2021). This approach applies problem-based learning by utilizing scientific research and mathematical applications, with technology design as a form of problem-solving (Irwanto, 2023). By using a STEM approach, the focus of inquiry learning is carried out by designing designs and technology to solve real problems (Pahrudin et al., 2021). Therefore, it plays a very important role in helping students acquire cross-disciplinary knowledge and skills.

Weak students' critical thinking skills will have an impact on students' ability to achieve success in learning, daily life, and the future. They are less objective and selective about problems that occur in real life so they are unable to contribute to solving problems. The study results also highlight the importance of STEM education in the 21st century and the need for practical applications in education and careers (Abdurrahman et al., 2019). Many experts have tried to develop things related to STEM learning, but integrating inquiry and STEM in learning is still limited to strategy design so further research is needed to ensure its effectiveness in various scientific disciplines (Agustina & Dwikoranto, 2021; Jeon et al., 2021; Onsee & Nuangchalerm, 2019). Therefore, researchers conducted preliminary research to determine the level of students' critical thinking skills and determine the extent to which the integration of inquiry-based STEM learning is implemented in schools.

Method

The research method used is a survey research method which is the initial part of development research. In development research, there are several methods used, namely descriptive methods (surveys, case studies), evaluative, experimental, and others (Danuri & Maisaroh, 2019). Survey research is carried out to collect information and data to draw generalizations from observations that are not too in-depth so that answers and solutions to a problem can be found (Prasetia, 2022). In this case, survey research aims to collect data and information about physics learning problems in schools related to the inquiry learning model, STEM integration in learning, and the level of students' critical thinking skills. The instruments used in this research were (1) teacher interviews, (2) tests of students' critical thinking skills, (3) analysis sheets of the teaching materials used, (4) teacher learning observation sheets. The data that has been obtained is analyzed quantitatively and qualitatively. The teacher interview respondents consisted of 4 teachers from 4 different schools.

The research sample that was given the critical thinking skills test consisted of 60 class 10 students from the four schools. The critical thinking skills test instrument consists of 5 essay questions on rotational dynamics and equilibrium of rigid bodies. Indicators indicating critical thinking skills categories are described in Table 1.

Table 1. Critical Thinking Skills Indicator

Indicator	Description
Analysis	Check information systematically
Evaluation	Logically assess credibility, relevance, strengths, and weakness
Inference	Draw logical conclusions
Interpretation	Explain with meaning
Explanation	Clarify and enlarge one's conclusions based on facts
Self-Regulation	Ability to monitor, control, and adjust thinking, learning, and problem-solving processes

(Dumitru et al., 2018; Duran & Dökme, 2016; Karahan et al., 2023).

Result and Discussion

The results of interviews with 4 respondents showed that almost the same problems occurred in the four school classes, as depicted in Table 2. In general, teachers still carry out conventional teaching, namely teacher-centered learning. Teachers explain more teaching material, and students are less actively involved in learning. There are very few discussion and presentation activities that train communication and collaboration skills between students. Investigation activities are also rarely carried out so students' skills in managing data collection, data analysis, and evaluating findings are also lacking, even though in designing learning tools the teacher has used several learning models recommended by the curriculum but each stage has not been implemented optimally during the learning process. Students are also rarely involved in learning activities based on science, technology, engineering, and mathematics which can encourage thinking skills. This means that learning at school has not fully trained students' skills, namely critical thinking skills, through the existing learning process.

In addition, teacher-centered learning results in students not understanding concepts and only being interested in memorizing formulas. Teachers' efforts to improve students' critical thinking skills are only by providing more complex practice questions and discussing the solutions in class. This shows that there are problems in the process of forming students' thinking skills, especially critical thinking skills. The low critical thinking skills of students can be seen from the results of critical thinking tests given to 60 sample class students from 4 different schools. The results of the critical thinking test given to 60 sample class students from 4 different schools are shown in Figure 1.

Figure 1 shows the results of the analysis of each indicator of critical thinking skills for class 10 students from the four sample schools. In the aspect of analyzing questions, an average of 44.7% of students already have them. Students can evaluate the information they obtain by 51.2%. In the aspect of inference and interpretation, students have an average percentage that is not too different, namely 43.45% and 42.25%. For the evaluation section, students had a percentage of 33.1%, which shows that students tend not to provide further explanation about the results they obtained after completing the calculations. The self-regulation aspect has the lowest average percentage, amounting to 19.98%. This shows that students cannot yet organize and control their thinking processes well.

Table 2. Interview Result with 4 Hight School Teachers Respondents

Question	Response
What methods have been used during learning?	The teacher explains the material more (lecture method). Even though I have designed Inquiry, PjBL, PBL models, and so on, they are difficult to implement during the learning process
Have you ever integrated STEM into learning?	Teachers in one school have integrated STEM with the PjBL model in learning, but the implementation has not been optimal. Several other schools have never integrated STEM into learning
Do students understand physics concepts well or just memorize formulas?	Some students understand physics concepts well, but most students are more interested in memorizing formulas
How can to improve students' critical thinking skills?	Students are given practice questions at a more complex level

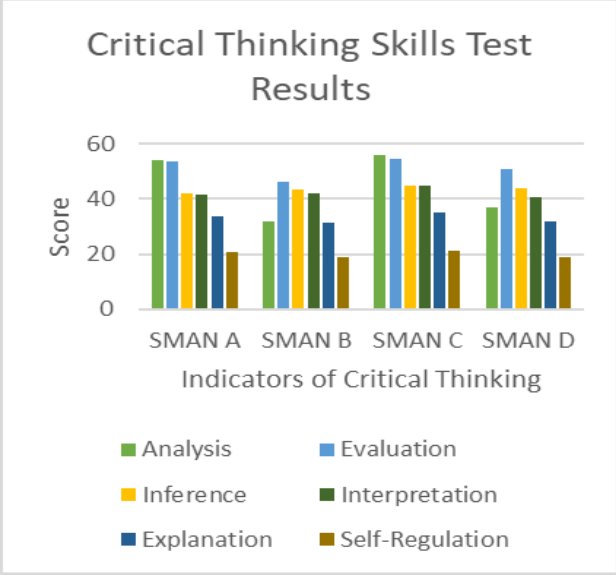

Figure 1. Critical Thinking Skills Tests Result

Poor critical thinking skills are a problem that often occurs in high school students and college students. The results of the research show that 70% of high school graduates do not have good competencies involving aspects of critical thinking skills and over 4 years students only have 28% of critical thinking skills (Wartono et al., 2018). In addition, students who have better critical thinking skills will achieve better learning outcomes compared to students who have low critical thinking skills. This is because critical thinking consists of the ability to understand what we know, what we think, what we do, and how we do it (Wahyuni, 2019).

Furthermore, the results of observations of teacher learning implementation also show that the process of forming students' critical thinking skills which is observed through the implementation of each stage in the inquiry learning model used by teachers has not been implemented optimally in the learning process. This is shown in Figure 2 which states that from a score range of 0 – 4, the implementation of each stage of inquiry in learning is dominated by obtaining a score range of 1 – 2. This shows that the implementation of learning has not been optimal in encouraging the improvement of students' critical thinking skills.

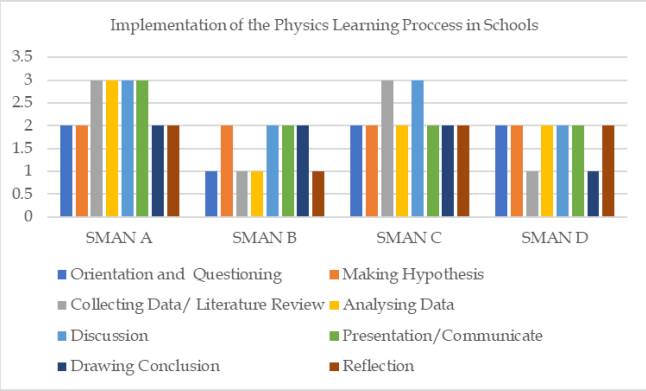

Figure 2. Implementation of learning

Students' low critical thinking skills, which are a basic need to face the era of revolution 4.0, need to be addressed (Thornhill-Miller et al., 2023). Teachers who act as mediators and facilitators must create and implement learning strategies, models, and methods that can help students learn to think critically (Ijirana et al., 2022). Critical thinking skills can also be empowered by providing questions or problems that challenge students' thinking or through certain experimental tasks that vary according to the topic being studied (Houdé & Borst, 2014). In this way, students thinking structures will improve.

As a solution to the problems described above, it is necessary to develop teaching materials that contain various activities to improve students' critical thinking skills. Teaching materials are also designed to increase students' understanding of physics concepts and their integration with science, technology, engineering, and mathematics (Amin et al., 2022). Teaching materials are equipped with experimental activities consisting of several variables so that students can vary variables in finding physical equations. One learning model that has a positive impact on improving critical thinking skills is the inquiry learning model (Kusumi, 2019). The teaching materials that will be developed can generally train students' skills to face the 21st century.

Conclusion

The implementation of physics learning in schools is dominated by conventional or teacher-centered methods. Current learning does not fully utilize the inquiry process to improve students' critical thinking skills, and students' understanding of STEM integration in physics learning is still low. This can be seen from the teaching materials used in schools that do not fully integrate STEM. The application of each stage of inquiry to encourage increased students' critical thinking in the learning process and the teaching materials used have not been implemented thoroughly. This is shown from the results of observations and test results of students' critical thinking skills which are still low. Therefore, this preliminary study concludes that integrated inquiry-based STEM physics teaching materials must be developed so that students can improve their critical thinking skills to meet the demands of 21st-century skills.

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Conceptualization, validating the instrument, guiding the research process, and writing an article, S.S.; creating research instrument, conducting research and writing articles, N.J.F.

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