

ELEMENTARY SCHOOL TEACHERS' PERCEPTIONS OF CRITICAL THINKING IN STEM LEARNING

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ABSTRACT

The character development of Indonesian students is directed towards teaching students to form critical thinking skills. In forming critical thinking skills, one of the parties that play an important role is the teacher. In addition to critical thinking skills, the competencies that students are expected to master include Science, Technology, Engineering, and Mathematics (STEM). However, there is little research on teachers regarding critical thinking in STEM learning despite it is the teachers who are expected to teach this skill to students. This study aims to determine the teacher's perception of critical thinking skills in STEM learning. The participants were 67 elementary school teachers in one district in Bangka Belitung Province. Data were collected through a questionnaire given after the teacher was given brief information about Critical Thinking. The results showed that teachers' perceptions of critical thinking in STEM learning were very diverse. Teachers in this study also perceive students' abilities as a constraint. The results of the study encourage the need for training on critical thinking for elementary school teachers.

Keywords: Critical thinking, categorical syllogism, primary school, teacher, STEM

1. PREFACE

The development of critical thinking in industry 4.0 has become an important skill in various fields, especially in education and professionals. However, in terms of operational definitions, teaching and assessment have not been applied properly so it becomes a challenge for teachers in developing critical thinking skills in students [1]. This is one of the reasons the school curriculum helps students gain knowledge, learn new skills, and develop the attitudes needed in real-life situations. To obtain a competency, it is necessary to know what students need in learning by critically reflecting on the student's learning objectives [2]. Students with more critical thinking skills and insight will show better academic performance in school and will also be better prepared to solve problems and increase academic expectations in the future [3].

A study [4] showed a significant relationship between teachers' critical thinking skills and students' academic achievement. Research findings by Tanriverdi et al. [2] shows that the role/attitude of the teacher is an important factor in developing students' critical thinking skills, and the teacher education curriculum should be enriched with multidisciplinary training and further development of the teacher education curriculum is needed. The way the teacher conveys and directs information to students can affect students' critical thinking skills [5].

The current learning approach in education seems to be still lacking in encouraging students' critical thinking learning [6]. Teachers' perceptions play an important role in influencing the student's teaching system, especially students' critical thinking processes. Teachers need to change the perception that students cannot learn unless the teacher helps them, while being

flexible and directs students that every problem has more than one solution to overcome it. It is intended that students can learn actively and improve their critical thinking skills [6,7]. A study [8] also show that teachers' knowledge of critical thinking should be improved so that teachers can reflect on their abilities related to subsequent learning tasks. The improvement of critical thinking skills has developed rapidly since the 21st century and has become a significant criterion in assessing school curriculum outcomes [9]. Emphasis on the development of critical thinking skills of teachers in the school curriculum is needed so that students can solve personal and social problems, and become more active [10].

Definition of Critical Thinking in STEM Learning

Critical thinking ability is broadly defined as a collection of processes with several main dimensions: interpretation of the world, self-reflection, intercultural awareness, critical awareness, giving arguments, and solving problems [11]. Critical thinking can also be defined as the analysis and evaluation of information, developing a reasoning and analysis, as well as evaluating information, according to standards. These standards are in accordance with the objectives to build new knowledge that makes sense, expanding insight, understanding, and belief. Critical thinking includes the individual's ability to process and synthesize information in such a way that it can be applied appropriately and wisely for appropriate decision making and effective problem solving [1].

The National Council for Excellence in Critical Thinking (NCECT) defines critical thinking ability as an active cognitive process of conceptualizing, applying, analyzing, synthesizing, and/or evaluating information. The information in question is information generated from observation, experience, reflection, reasoning, or communication [12]. The need for critical thinking skills training must also be accompanied by an intellectual character development strategy so that it is in line and more effective [13]. There are many strategies for developing critical thinking skills such as dialogue opportunities between students and teachers who ask questions. Research [14] found that students need active learning activities in the classroom to train critical thinking, and specifically, this strategy can be integrated through STEM activities.

STEM is part of today's school curriculum. Many activities have been designed and implemented by the teacher by involving students in learning. STEM can increase students' interest in problem solving and communication. When students explore a problem in STEM, students are indirectly involved in solving problems individually and in groups. This enables students to arouse curiosity and critical thinking skills when involved in problem solving [15]. The many points of view on STEM add further complexity in solving a problem [16]. There are many approaches to STEM that can assist students in solving problems by applying cross-disciplinary concepts as well as capacities in critical thinking. However, most teachers have received training in only one discipline, and some have studied STEM separately [17].

Studies on Critical Thinking at All Levels of Education

A study [18] found several factors related to students' mathematical reasoning abilities, namely: (a) skilled students, can use inductive and deductive reasoning abilities well and can solve quadratic equations in the form of stories well and precisely according to the steps; (b) students with moderate abilities, use inductive and deductive reasoning abilities quite well and can solve quadratic equation problems in the form of stories well, but are less able to find other ways to answer questions; (c) students with low abilities tend to be poor in reasoning abilities and are less able to solve problems and are less able to determine other ways of solving problems.

Another study [19] regarding students' critical thinking in STEM education was carried out through Project Based Learning designing tools to clean waste. The results of this study indicate that in critical thinking, there are students who are higher thinkers (41.6%), average thinkers (55.6%), and lower thinkers (2.8%). The average thinker is a category in which students have sufficient thinking skills in criticizing their own plans in systematic practice and criticizing realistically regarding students' own thinking.

The results of another study [20] also showed that there was a positive effect of STEM education on students' critical thinking skills towards the applied STEM activities. These activities make a positive contribution to students' awareness of their next career related to STEM. Some students still have the perception that the STEM field is a difficult field. However, students become aware of the importance of studying engineering.

Categorical Syllogism in Individual Thinking Process

Critical thinking skills include several sub-abilities. One part of critical thinking skills is the categorical syllogism. A syllogism is a deductive inference process. The conclusion of a syllogism can be general or less general than the premises. If the premises are true, then the conclusion is true, and if one of the premises is false, then the conclusion is false.

A pure categorical syllogism accepts all the rules and norms of a formal syllogism which is deductive inference. A categorical syllogism consists of three categorical propositions, namely the major premise, minor premise, and conclusion. In this case, Aristotle gave the statement "Dictum de omni et nullo". This statement can be interpreted in English as 'the maxim of all and none' which means for each proposition, what is true for a particular class is true for members of that class, and what is not true for a particular class is not true for members of that class [21].

An example of the Dictum de Omni et Nullo is as follows: (a) no man is perfect, (b) Gandhi was a man, (c) therefore, Gandhi was not a perfect being, (d) in this argument, it is stated that 'male' (i.e. class) is not a perfect being. Gandhi was a man belonging to the 'male' class, and therefore Gandhi was not a perfect being. This argument holds that whatever is not true for everyone, is not necessarily true for Gandhi as an individual member belonging to the 'male' class [21].

A study by Cagnin and Leme [22] illustrates that gender is related to ability in categorical syllogism. This study found that women tend to be more sensitive to negative syllogistic statements than men. This provides an understanding of the impact of the content of evaluative statements that require deductive reasoning abilities, especially in education and professional activities of students based on gender.

Research on Critical Thinking in Elementary School Teachers

Teaching skills and material delivery are important for a teacher to take a professional approach to develop students' thinking skills. In the industrial era 4.0, every country has a way of surviving by mobilizing thoughts and making competitive improvements in Human Resources (HR). One example is seen in the field of education which is carried out by carrying out training to form and produce quality teachers. A systematic literature review was conducted to determine the professional competence of teachers. The way students think is influenced by several factors where one of the environmental factors is school [23].

Teachers play a very important role towards students because students view teachers as perfect role models. Teachers in any field have a great responsibility and influence on the future of a

country with the formation and development of students' character in the future [24]. The use of reflective thinking and teaching practice is one way to stimulate critical thinking in teachers and many teachers assume that they have or need to teach critical thinking skills [25].

A study [26] was conducted on 60 teachers through a questionnaire as a measuring tool or indicator of the level of critical thinking skills of participants in the context of teaching. The study showed that most of the teacher participants did not understand how to practice critical thinking in the context of teaching. In this study, there are four learning processes studied, namely: assumption analysis, contextual awareness, imaginative speculation and reflective skepticism. These four things are an indication of reflective thinking. The study shows the lack of critical thinking practice, and recommends further research to seek critical thinking among teachers.

Karagöl and Bekmezci [26] added, that to form students who ask questions actively, can think critically, and can research, teachers are required to have these skills first. The results of the study show that there is no significant difference in the critical thinking tendencies of prospective teachers based on gender. The critical thinking disposition of teachers has a weak correlation with academic achievement.

Özelçi dan Çalışkan [27] interviewed 11 teacher candidates twice over four years. The results of the interview show that prospective teachers use perceptions based on their experience regarding their critical thinking teaching to students. This situation shows that there are prospective teachers who do not meet the requirements for critical thinking, and this is one of the problems that need attention, and further training is needed in this regard [27].

How to Improve Students' Critical Thinking Ability

Creative problem solving, as well as possession of unique insights for appropriate solutions, require more critical thinking skills. This ability also requires students' confidence in doing so. Teachers and school administrators are responsible for this teaching and learning process, because students need frequent and repeated teaching of critical thinking practices, and the training must start at an early age [3]. The results of Tiatri and Jap's research [28] found that digital technology has the potential to be a tool that can improve students' thinking skills. Thus, digital technology has the potential to improve critical thinking skills.

Birgili [29] found a way to improve students' critical thinking skills through instructional strategies, namely through problem-based learning or discussion activities. This is done by paying attention to differences in solutions and problems and adopting a skeptical perspective when viewing an event or condition. In addition to instructional strategies, goal assessment techniques may also be a formative assessment technique. This way, both the product and the process can be evaluated.

The inquiry-based learning (IBL) approach emphasizes students through experience and construction. This approach helps students become active in the learning process such as asking questions, researching, and solving problems. This approach is widely used in science education [30]. The application of inquiry-based learning (IBL) to a group of students showed positive results that affected the improvement of students' critical thinking skills. This is different from a group of students who still use ordinary learning through traditional learning methods. Using traditional learning methods is considered less effective in improving students' critical thinking [31].

One method for strengthening pupils' mathematical comprehension abilities and raising academic achievement was to use critical thinking. In high school, pupils who used inquiry-discovery based learning demonstrated stronger critical thinking than those who learned using the conventional technique. Students actively participated in the inquiry-discovery learning approach and their knowledge improved through theoretical and empirical reviews [32].

Obstacles in Teaching Students Critical Thinking Ability

The findings from the research of Sağlam and Büyükuysal [33] show that students' critical thinking levels are generally low. The critical thinking ability of students differed significantly by gender, with a better ratio in male students. During group interviews, it was seen that the education system, family environment and social traditions, educational environment, and instructors/academics could be obstacles to critical thinking.

The biggest obstacle in teaching critical thinking is the failure to adapt students to an educational environment that embraces critical thinking starting at the elementary school level. Teaching critical thinking needs to start from preschool to higher education. The development of critical thinking learning can be assisted by creating a physical and psychological environment, encouraging communication and interaction in the classroom, reviewing the educational curriculum, and maximizing opportunities for participation, discussion, and research for prospective teachers [33].

The interviews by Sağlam and Büyükuysal [33] with teachers show that the family background and educational environment that dominates students can have a negative impact, making students more hesitant and lacking confidence to express their thoughts and opinions in class. Family compliance culture is one of the obstacles so students must try harder in improving critical thinking skills. Another thing that hinders students' critical thinking skills in today's digital world is the school environment such as limited time, excessive teacher working hours, insufficient classrooms, access to the internet, and school buildings, as well as the education system such as curriculum materials that are less supportive in developing students' critical thinking learning [33].

A study by Goodwin, Healy, Jacksa, and Whitehair [34] show two main barriers to STEM-based learning programs. First, increased attention to educator accountability has led to increased reliance on standardized tests as an evaluative measure for students as well as educators. As a result, preparation for exams is a major goal for many educators. However, the World Economic Forum says 35% of the skills deemed essential in the 2015 workforce are obsolete by 2020. There is growing evidence to show the importance of soft skills but the pressure to prepare for high-stakes exams is a strong disincentive to spend instructional time on any activity that is not directly related to the preparation. Second, most educators are not formally trained in the concept of STEM education. Often, educators in non-STEM subjects are intimidated by what is perceived as extraneous content unrelated to the subject matter for which they are responsible. In addition, the increased emphasis on accountability has led some school districts and state education departments to provide classroom teachers with a compact and standardized curriculum at the 2017 IEEE Integrated STEM Conference (ISEC). The implementation of this curriculum is adjusted to the school calendar which aims to leave less time to integrate activities and concepts that are not part of the curriculum.

Based on the literature review on Critical Thinking described above, before implementing the program to improve critical thinking skills, this study intends to obtain an overview of teachers' perceptions of critical thinking, especially in the context of STEM learning.

2. RESEARCH METHOD

This research uses descriptive quantitative method. This study involved 67 elementary school teachers in one of the districts in Bangka Belitung Province. Data were collected through questionnaires distributed in teacher meetings related to critical thinking knowledge. Researchers provide a brief introduction to critical thinking knowledge, through lectures, discussions, short questions and answers.

The questionnaire given to the research participants contained brief questions regarding the teacher's opinion in three respects, namely: (a) understanding of critical thinking, (b) how to improve students' critical thinking skills, and (c) obstacles faced by teachers in improving students' critical thinking. The teachers wrote a short description of their opinion in response to the three questions. In data processing, their answers are grouped into categories based on the similarity of the main point.

3. RESULT AND DISCUSSION

The processing of this research data shows the most common opinions expressed by the participants. These opinions can be considered the best representative of the teacher's perception of critical thinking.

Definition of Critical Thinking according to Teachers

The research data shows that there are three categories of ideas put forward by the teacher regarding the definition of critical thinking, namely: (a) drawing conclusions based on logical observations/reasoning abilities; (b) improving student character/related to student ability; (c) integrate the mindset in everyday life. Based on the percentage of answers, the most common idea put forward by teachers (53.1%) is that the definition of critical thinking in STEM is to think reflectively, and the ability to understand, reason, analyze data based on observations so that they can draw conclusions, solve a problem, and communicate effectively with others. These teachers' perceptions are in line with the definition of critical thinking expressed by Heard, et al. [1], namely that critical thinking is defined as the analysis and evaluation of information, developing a reasoning against information in accordance with standards, so that it can be applied in making appropriate decisions and effective problem solving.

Table 1.

Definition of Critical Thinking by Teachers

Categories of Teacher's Answers on the Definition of Critical Thinking	Percentage of teachers
Draw conclusions based on logical observation/reasoning ability	53.1%
Improving student character/ related to student ability	31.3%
Integrating mindset into everyday life	15.6%

How to Improve Students' Critical Thinking Skill in STEM

The second question that the teachers needed to answer through description is about improving students' critical thinking skills, especially in STEM learning. Most (70.3%) teachers involved in this study thought that the way to improve students' critical thinking skills was by providing a stimulus to students so that students felt compelled to work together in making decisions or solving problems at hand, creating a conducive atmosphere, inviting students to work together. recognize, record, process, present, analyze data and conclude data. The teacher also lets students explore the activities that are followed with the aim of stimulating students' critical thinking.

This is similar to the opinion by Birgili [28] regarding how improving critical thinking skills can be done with an instructional design system, namely providing teaching by inviting students to discuss and develop different points of view so that different solutions may emerge. The opinion of the teachers is also quite similar to the opinion of Huang, et al. [30] that students need to be required to be active in the learning process such as researching together and solving problems together which is called inquiry-based learning (IBL).

Jackson, et al. [35] developed an empirically based theory of action for instructional improvement in mathematics. These authors state that the five interrelated components needed to support “ambitious teaching” are (a) instructional materials and guides; (b) teacher professional development and collaborative meetings; (c) work embedded support for teacher learning; (d) school instructional leadership; and (e) school system leadership.

Table 2.

Improving Students' Critical Thinking

Categories of Teacher's Answers on How to Improve Students' Critical Thinking Skills in STEM Learning	Percentage
Provide activities / stimulus to students	70.3%
Encourage/involve students in various ways	26.6%
Other things not identified	1.6%

Teacher Constraints in Teaching Critical Thinking in STEM Learning

The third question in the questionnaire is about the teacher's perception of the obstacles faced by the teacher while in the field teaching critical thinking skills. Most of the participating teachers (53.1%) stated that the obstacle faced was the students' skills. The students' abilities in question range from: (a) cognitive abilities, (b) learning concentration levels, (c) students' emotional levels, (d) potential, (e) students' self-confidence, (f) analytical skills, (g)) student's ability to think, (h) student's learning ability, (i) ability to adapt to technology, (j) literacy ability, (k) mathematical ability.

The perceptions of the teachers participating in this study are in line with the findings of Abdulazeez and Ali [36] that the obstacles faced by teachers in encouraging students' critical thinking include shy students and students who have doubts about expressing opinions. The lower thinking capacity of students and the mental condition of students affects the learning process.

Table 3.
Obstacles on Critical Thinking Learning

Categories of Teacher's Answers on Obstacles in Teaching Critical Thinking in STEM Learning	Percentage
Student Interest	7.9 %
Student Mindset	7.8%
Student Ability	53.1%
Student Facilities and Infrastructure	23.4%
Other things not identified	6.3%

4. CONCLUSIONS AND RECOMMENDATIONS

This study uncovered an overview of the teacher's perception of critical thinking. Most of the teachers (53.1%) mentioned the definition of students' critical thinking ability which was in line with the expert opinion regarding the definition. Most teachers (70.3%) also understand how to encourage students' critical thinking skills, namely by providing stimuli or activities that require collaboration, activeness, and problem-solving in students, although the teachers did not specify what activities should be given to students. In addition, most of the teachers (53.1%) perceive students' skills to be an obstacle that must be faced by teachers in teaching critical thinking to students. The students' skills are influenced by the family and social environment which may become an obstacle for students in developing cognitive abilities. The results of this study indicate that training on critical thinking for elementary school teachers still needs to be studied further.

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