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Changes in Students' Cognitive Abilities through STEM-Based Learning in Elementary Schools

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Abstrak

Perkembangan siswa menguasai materi pelajaran berkaitan dengan kemampuan berpikir siswa. Oleh karena itu, penelitian ini bertujuan mengetahui perubahan kemampuan kognitif siswa tingkat sekolah dasar menggunakan pembelajaran berbasis STEM. Penelitian ini menggunakan metode deskriptif. Partisipan penelitian dipilih berdasarkan kategori tinggi, sedang dan rendah masing-masing satu orang. Pengumpulan data dilakukan wawancara tidak terstruktur dan hasil analisis menggunakan analisis deskriptif kualitatif. Hasil penelitian terdapat perubahan kemampuan kognitif siswa melalui pembelajaran berbasis STEM. Hal ini dikarenakan setelah melakukan pembelajaran berbasis STEM, ketiga partisipan memenuhi seluruh karakteristik kemampuan kognitif atas dasar hasil wawancara yaitu mampu mengingat, memahami, menerapkan, menganalisis, mengevaluasi dan menciptakan materi sumber energi yang dikaitkan pada materi penyajian data.
Kata Kunci: Kemampuan Kognitif; Pembelajaran Berbasis STEM; Siswa Sekolah Dasar.

Abstract

The development of students mastering the subject matter is related to students' thinking abilities. Therefore, this study aims to determine changes in the cognitive skills of elementary school students using STEM-based learning. This research uses a descriptive method. Research participants were selected based on each person's high, medium and low categories. Unstructured interviews were carried out for data collection, and the analysis results used descriptive qualitative analysis. The results of the study showed changes in students' cognitive abilities through STEM-based learning. The impact occurred is because after carrying out STEM-based learning, the three participants fulfilled all the characteristics of cognitive skills based on interview results, namely being able to remember, understand, apply, analyze.
Keywords: Cognitive Ability; STEM-Based Learning; Elementary School Student.

I. INTRODUCTION

Learning is essentially a process of helping students to learn well. Where the learning process is not only dominated by the teacher but there are active and creative student activities in developing their learning independently, including mathematics and Science (Dewi & Hamdu, 2020).

Mathematics and science are learning that are close to life. However, mastery of the material, and technical skills in using formulas and arithmetic, cannot be said to develop skills to become the essence of learning mathematics itself (Sumaryanta & Wibawa, 2020).

Mathematics is a subject that must be studied as one of the sciences needed by students to have critical thinking skills and be able to solve problems. When the learning process starts, students are constantly faced with understanding the content of the material being taught in mathematics learning itself without exception to various issues that will be met by students, such as solving problems in the form of questions or tasks that students will complete. In addition, there may be problems that students in learning science will obtain.

Science learning focuses elementary school students on understanding science concepts and critical thinking. In line with(Safira et al., 2020), science learning can be used as a problem solving when it is identified in everyday life.

According to Piaget in Hardani (2020), the age of students at the elementary school level is included in the concrete operational stage category. In this tangible-active stage, students' cognitive changes occur toward logical thinking from before. One of these thoughts will later be used when learning in class. However, the learning process occurs by relying on the statement, "the important thing is that learning has been carried out" this statement makes the development of students' cognitive abilities not achieved, especially during the implementation of Math and Science learning.

The learning process that occurs in Mathematics Subjects is that students feel that mathematics is complicated; it makes the learning atmosphere in class dull, students' interest in understanding and even participating in mathematics learning is lacking, and students lack motivation to participate in mathematics lessons because it has been recorded in students' thinking that Mathematics lessons are tricky, especially since most of the students are weak in metacognition abilities. In line with(IDCK Putri & Widodo, 2018), some of the causes of low student achievement are due to a lack of student understanding of previous material, student attention when learning is carried out is still lacking, and student activity in class is also still low.

The statement above is consistent with the characteristics of learning difficulties in mathematics, namely: 1) difficulty distinguishing numbers, symbols, and geometric shapes, 2) cannot remember mathematical arguments, 3) writing numbers in small sizes, 4) do not understand mathematical symbols, 5) weak abstract thinking skills, 6) weak metacognition skills (Wood in (Saja'ah, 2018)). In addition, the same thing also happened in science learning.

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The purpose of learning science is to give students a conceptual understanding of the relationship with natural phenomena in everyday life and instil a scientific attitude. In line with (Safira et al., 2020)argued that science learning aims to help students understand science concepts related to natural phenomena in everyday life.

In this learning, various problems need solutions; learning in class still uses conventional methods that make students passive, not paying attention, and sleepy during the learning process.

This problem makes students' cognitive changes decrease so that they need to be honed so that when they reach the concrete operational stage, they can have creative, critical, innovative thinking skills, are even technologically literate, and will be helpful when carrying out the problem-solving process.

The cognitive ability in question is when students can think and solve a problem that can later be assessed. Knowledge Cognitive skills can be seen in Bloom's taxonomy revised by Anderson, et al (2001) as follows: remember, understand/understand, apply, analyze, evaluate, and create. Bloom's taxonomy is designed to differentiate thinking skills from the lowest level to the higher level of thinking (Arlianty et al., 2018).

According to Huda, 2013 in (Susanti 2018), applying all students' cognitive abilities in learning can improve the quality of education, especially in solving problems. In solving a problem, of course, every student has their way of solving it depending on their cognitive abilities, one of which is by using a practical approach.

The approach in question is the STEM (Science, Technology, Engineering, and Mathematics) approach. STEM (Science, Technology, Engineering, and Mathematics) is an integrated approach focusing on the learning process of solving real-life problems aimed at developing student creativity, especially in Mathematics and Natural Sciences.

In line with the 2013 Curriculum in (Davidi et al., 2021) stated that to prepare Indonesian students to acquire 21st-century skills, namely thinking skills through critical thinking, creative thinking, and solving problems, the STEM approach was adopted to strengthen the implementation of the National Curriculum.

The STEM (Science, Technology, Engineering, and Mathematics) approach is an effort that can be made and is needed to improve the quality of Human Resources and cognitive abilities. As an approach, STEM (Science, Technology, Engineering, and Mathematics) is an approach that integrates Science, Technology, Engineering, and Mathematics education which will be focused on solving problems in everyday life. According to Davidi, et al. (2021), there are four STEM (Science, Technology, Engineering, and Mathematics) disciplines which are summarized as follows:

1. *Science* contributes to developing interests and understanding related to the living world, collaboration skills, materials, research, physics, critical inquiry, and experimentation.
2. Technology makes it possible to be involved in applying knowledge, skills, thinking, and solving problems using

algorithms (computation) which will later be used to expand capabilities and help all human needs and desires.

3. Engineering is knowledge and skills that have benefits for solving problems in real life by designing and building equipment or machines to support problem-solving.
4. Mathematics provides knowledge and skills in interpreting and analyzing information, assessing risks, simplifying and even solving problems, making decisions based on accurate information, and understanding the surrounding environment by modelling abstract and concrete situations.

Several studies related to STEM (Science, Technology, Engineering, and Mathematics) learning use it to improve students' cognitive abilities(Firdaus & Rahayu, 2019; Hasanuddin et al., 2022). STEM (Science, Technology, Engineering, and Mathematics) learning which is used to improve students' cognitive abilities, can be applied in various situations. This approach can do things as mentioned above because STEM (Science, Technology, Engineering, and Mathematics) learning involves physical experiments and critical thinking to solve abstract and concrete problems. However, few research results still discuss cognitive changes obtained through STEM-based learning. Therefore, this research focuses on changing students' cognitive abilities through STEM (Science, Technology,

Engineering, and Mathematics)-based learning in elementary schools.

II. METHOD

The research was qualitative with a descriptive method that aims to describe changes in students' cognitive abilities through STEM-based learning (Science, Technology, Engineering, and Mathematics). Qualitative research is research that does not use quantification or statistical analysis procedures but the research that produces analytical techniques (Moleong (2010) in Kusumastuti & Khoiron (2019)). This research was conducted in four stages.

The first stage is carried out through the provision of initial diagnostic test sheet instruments in the form of Math and Science questions, namely changes in energy and bar charts which the expert has validated with ID Scopus 57208338065 and the expert with ID Sinta 6644534 stating that this test sheet is suitable for use, then prospective participants answer the questions accordingly. At one's pace for 60 minutes. After that, it is continued with the analysis of the results of the answers from the tests that were carried out.

The prospective participants in this study were 24 people taken from Class IV B students. Based on the results of the initial diagnostic test analysis, all potential participants were grouped according to the results of the test analysis into 3, namely, high, medium, and low regarding the research interval according to Buranda & Bernard (2018) in(Annisa et al. 2021)in table 1.

Table 1.
Convert Grades into Capability Categories

Score (%)	Indicator	Number of True Participants
80.0value 100≤≤	High	3
60.0value 80.0≤≤	Medium	8
value 60.0≤	Low	13

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In the second stage, after grouping the test analysis results, three groups were obtained on the initial diagnostic test results: high, medium, and low.

The third stage is continued with STEM-based learning (Science, Technology, Engineering, and Mathematics). STEM-based learning (Science, Technology, Engineering, and Mathematics) is applied to students to strengthen and facilitate students' understanding of energy changes and bar charts before being given a final diagnostic test. After learning is over, giving the last diagnostic test instruments to P1, P2, and P3 as energy change questions and bar charts, the prospective participants answer questions according to their abilities and self-development obtained through STEM-based learning (Science, Technology, Engineering, and Mathematics). After that, it is continued with the analysis of the answers from the tests that P1, P2, and P3 have carried out.

In the fourth stage, unstructured interviews were conducted with P1, P2, and P3, which represented each category and were randomly selected based on the initial diagnostic value. The interviews were conducted referring to the cognitive domain of bloom taxonomy keywords revised by Anderson et al. (2001): remember, comprehend, apply, analyze, evaluate, and create. Next, analyze the results of the interviews of the 3 participants. The interviews conducted by the researchers with the 3 participants were used to determine changes in students' cognitive abilities, as seen in table 2.

Table 2.
Characteristics of Cognitive Ability

Cognitive Ability	Indicator
Remember	The ability possessed by students is in the form of recalling the material that has been studied. The operative words "Remember" include mentioning, drawing, identifying, quoting, explaining, counting, and registering.
Comprehend	The ability possessed by students is in the form of understanding the material that has been studied. The operative word "comprehend" is in the form of showing, giving examples, and comparing.
Apply	The ability possessed by students is in the form of student understanding which indicates that they have been able to develop and compile teaching materials that are already known. The operative words are classifying and explaining.
Analyze	The ability possessed by students is in the form of doing assignments or solving problems using stages or procedures. The process is to implement, run and compare.
Evaluate	The ability possessed by students is in the form of detailing a problem down to the smallest part and determining how the various elements are related. The operative word is rearranging.
Create	The ability possessed by students is in the form of combining several elements into a unified format. The procedure is planning, producing, and manufacturing.

III. RESULT AND DISCUSSION

In this section, data on changes in students' cognitive abilities will be presented based on the results of the initial diagnostic tests and final diagnostic tests carried out by students in solving Math and Science questions using the STEM (Science, Technology, Engineering, and Mathematics) learning approach. Then asked to provide an explanation based on the category by Anderson et al. (2001): remember,

comprehend, apply, analyze, evaluate, and create. Table 3 presents the results of the initial diagnostic tests at P1, P2, and P3.

Table 3.
Grouping of Preliminary Diagnostic Test Analysis Results and Post-Diagnostic Tests

Score (%)	Indicator	Participant	Preliminary Diagnostic Test Results	Final Diagnostic Test Results
$80.0 \leq x \leq 100$	High	P1	82	100
$60.0 \leq x \leq 80.0$	Medium	P2	64	100
$x \leq 60.0$	Low	P3	53	100

Table 3 shows that P1 is included as a high indicator because it can explain and work on energy sources, such as mentioning the change in wind energy, namely motion energy into electricity, then the bar chart notes and implements bar chart calculations when calculating stationery sales and the number of students who buy them. Meanwhile, P2 is included in the medium indicator because it can only identify and give examples of changes in energy sources from motion energy to electricity. At the same time, the bar chart material is poorly understood when shown questions about calculating the sale of stationery, and many students buy it. Then the last one, namely P3, is included in the low indicator,

From the explanation of the initial diagnostic test results, it can be seen that there are still participants who do not even fully understand the material about energy changes and bar charts, so a learning approach is needed that can be a solution to overcoming this, such as the STEM approach (Science, Technology, Engineering, and Mathematics).

Understanding through the STEM (Science, Technology, Engineering, and Mathematics) learning approach is an essential component of knowledge to solve a problem and bring out students' critical thinking. The statement above is in line with Ennies' opinion (in Davidi et al., 2021) that the application of learning with the STEM (Science, Technology, Engineering, and Mathematics) approach can help improve students' critical thinking skills which are characterized by the ability to solve problems, make decisions, analyze assumptions, evaluate and carry out investigations.

Classroom learning was also carried out using the STEM (Science, Technology, Engineering, and Mathematics) approach, and afterwards, a final diagnostic test was carried out on P1, P2, and P3 with the same material, namely energy changes and bar charts. After that, a satisfactory score was obtained for the results of the final diagnostic test, which can be seen in table 3. The following are the results of the work of the three participants.

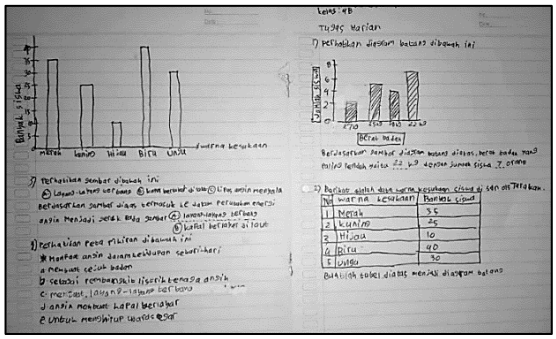

Figure 1. Results of Work on P1

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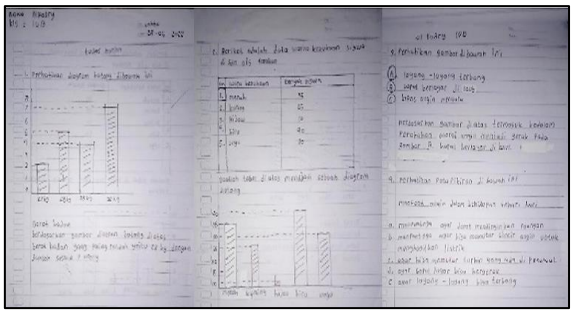

Figure 2. Results of Work on P2

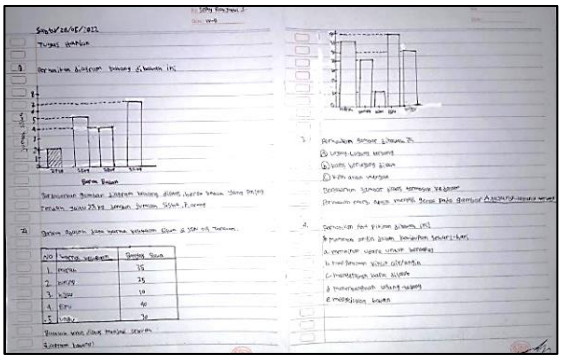

Figure 2. Results of Work on P3

The results of the work were confirmed through the interview as follows.

P1 expressed the opinion that:

"I can explain energy source materials and bar charts well. Energy sources are anything that can generate energy in the environment around us, whether directly or through a process of change, then a bar chart is a diagram that displays a square bar or beam used to show a change in data".

While P2 expressed the opinion that:

"I can identify the material sources of energy and bar charts well, for example, energy sources, namely, wind energy from motion energy changes to electrical energy then for bar charts it can be used in calculating data such as data on sales of stationery and the number of students who buy it."

P3 delivers:

"I can easily cite examples of these two materials, such as energy source materials, namely, wind, water, and solar energy, which are renewable energy sources, then bar chart material in calculating the amount of palm oil production per month, namely, in January, 1 ton per month."

The results of the interviews seem clear that P1, P2, and P3 can remember (explain, identify and mention) the contents of the material well; for example, energy sources clarify that everything that produces energy in the surrounding environment is determined by examples of motion energy turning into electrical power then bar diagrams is a diagram that displays a block to show data changes accompanied by illustrations, namely, sales of stationery and many students buy so that it can be said that participants understand the material.

Comprehending is aimed at the ability to understand the material or teaching materials. Cognitive domain C2 (Comprehend) is the ability to describe a material associated with other material. The statement was confirmed by conducting interviews at P1, P2, and P3.

P1, P2, and P3 expressed the opinion that:

"My understanding of the material on energy sources and bar charts is evident because energy sources produce heat energy, for example, solar energy, which is useful for plant development processes, and then by linking it to bar charts by calculating plant growth per week as explained by the teacher when learning with a STEM."

It seems clear that P1, P2, and P3 understand (give examples) material well, such as heat energy generated by the sun helping the process of plant growth and presenting plant growth data presented using bar charts when learning with the STEM approach.

The application of the material provided follows the cognitive domain C3 (Applying): the ability to use material learned and understood in concrete or new situations. The statement was confirmed by conducting interviews at P1, P2, and P3.

P1 and P3 expressed the opinion that:

"I can explain the lessons learned from energy sources and bar charts as energy sources are sources that exist in the surrounding environment such as wind, water, sun, and others, then a bar chart is a diagram used to present data such as stationery sales data as explained by the teacher".

P2 expressed the opinion that:

"In learning energy sources and bar charts that are taught through the steps or procedures for making windmills that experience energy changes from motion energy to electrical energy that is useful in everyday life and then linked to bar charts, namely data presentation in the form of many windmill rotations slow turn."

Based on the results of the interviews, it seems clear that P1, P2, and P3 can apply (procedure) material well because they explained the process or steps for making a windmill which will later find a change in energy and present data from the results of energy changes such as calculating the rotation of the windmill slow rotating wind to be analyzed.

The results of the interviews for categories C1 to C3 were that the three participants could remember, understand and apply the two materials correctly because the participants were able to explain the material well, such as an energy source is anything that produces energy in the surrounding environment. A bar chart is a diagram that displays a block for changes in data; for example, the heat energy generated by the sun helps the plant growth process. Then it presents plant growth data using bar charts when learning with the STEM approach, which will be applied to the method or procedure for making windmills which will later find a change in energy and present data from the results of energy changes such as calculating the rotation of a windmill that rotates slowly.

In line with the realms C1 to C3, it is included in developing low-order thinking skills. Low-level cognitive statements are the basis for higher-order thinking, and understanding primary material usually accommodates lower abilities because lower-level thinking skills are more prominent than high-level abilities(TR Effendi et al., 2018; Gustiwan et al., 2021; Ichsan et al., 2019). In addition, the next stage in the thinking process is analysis, evaluation, and creation.

The material analysis provided corresponds to the C4 cognitive domain (Analyzing), namely, the ability to break down the material into parts or components that are more structured and easy to understand. The statement above was confirmed by conducting interviews at P1, P2, and P3.

P2 and P3 expressed the opinion that:

"Learning energy sources and bar charts with the STEM approach helps in carrying out the implementation of the benefits of various energy sources such as water for cleaning clothes and heat energy in the sun which is useful for drying clothes, while bar charts are used to compare data that has been presented for example in comparisons of students who like the lesson mathematics and students who like science subjects in class 4B."

P1 expressed the opinion that:

"Energy sources and bar charts can be related to each other such as the implementation of the material, namely, the presentation of data that is calculated by looking at the rotation of the windmill blades, which is one of the energy sources."

It seems clear that the results of interviews P1, P2, and P3 analyze (implement, run and compare) the materials well because they can implement both materials, for example, mentioning the benefits of energy sources such as water for cleaning clothes and thermal energy from

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the sun can dry clothes and also compare calculations bar chart on the completion of students who like mathematics and students who enjoy science lessons in class 4B and calculate the rotation of windmill blades which are used as evaluation material in the learning.

Evaluation of learning material is carried out following the C5 cognitive domain (Evaluation), namely, the ability to think, which is the reverse process of thinking analysis; evaluation is a process that combines parts or elements logically so that they transform into a structured pattern or in the form of a new design. The previous statement was confirmed by conducting interviews at P1, P2, and P3.

P1, P2, and P3 expressed the opinion that:

"The conclusion obtained from these two materials is that energy sources are everything that produces energy in the environment around us, for example, water, wind, or sun. And a bar chart is a diagram that displays data such as stationery sales data or a comparison of the number of students who like the subjects that are visible from the results of the analysis that has been carried out."

Based on the results of the interviews, it seems clear that P1, P2, and P3 can evaluate (rearrange) the material well because they can categorize conclusions based on energy sources that exist in the surrounding environment, such as water, wind, sun and also data diagrams that have been analyzed in learning material with just like stationery sales data or a comparison of the number of students liking the subject.

Categorizing learning material that is carried out according to the C6 cognitive domain (Creating), namely, the ability to put things together. The statement was confirmed by conducting interviews at P1, P2, and P3.

P1, P2, and P3 expressed the opinion that:

"The material on energy sources discusses renewable and non-renewable energy sources, while energy changes in everyday life, such as wind energy into motion energy such as making a simple windmill associated with bar chart material such as counting the number of rotations of a mill's propeller. slow wind"

Based on the results of the interviews, it seems clear that P1, P2, and P3 were able to create (make) as well as implement the material well because when the participants made a simple windmill, then associated it with bar chart material such as counting the number of rotations of the windmill blades which rotate slowly.

The results of the interviews for categories C4 to C6, namely the three participants were able to apply, evaluate and create the two materials correctly because the participants were able to implement and mention the benefits of energy sources such as water to clean clothes and heat energy from the sun to dry clothes, besides that they also drew conclusions based on understanding of the material energy sources and bar charts for example energy sources that exist in the surrounding environment such as water, wind,the sun and the sale of stationery or the comparison of the number of students liking the subject and comparing the calculation of the bar chart on the completion of students who enjoy math and students who are fond of science lessons in class 4B as well as calculating the rotation of windmill blades and of course assembling or making windmills then get the diagram data

that has been analyzed on the learning material precisely such as the data on the number of rotations of the windmill propellers that rotate slowly and then counted.

In line with the realm of higher order thinking skills in the process of C4 and C5 as critical thinking, while C6 is part of the ability to think creatively, the ability to think critically and creatively is used to solve problems or create solutions to make decisions. Higher-order thinking skills occur when a person takes new information and stores it in his memory, then connects it and conveys it to achieve the goal or answer needed (; Zamani & Rezvani in(CM Putri et al., 2021)).

The findings of this study are that if the participants understand and create MATH AND SCIENCE learning about energy resources and bar charts well, changes in cognitive abilities will be seen because learning uses a STEM (Science, Technology, Engineering, and Mathematics) approach and vice versa if participants find it challenging to understand and create Math And Science learning it is difficult to see changes in participants' cognitive abilities even though learning uses a STEM (Science, Technology, Engineering, and Mathematics) approach.

IV. CONCLUSION

From the discussion results, it can be concluded that changes in the cognitive abilities of fourth-grade students in STEM-based learning experienced significant changes when testing the initial and final diagnostic tests in the cognitive domains C1 to C6. In the initial diagnostic test, students with high cognitive abilities fulfilled the characteristics of remembering, understanding, applying, and analyzing, while students with moderate abilities fulfilled the attributes of recognizing and understanding. Then students with low abilities are less able to meet the characteristics of cognitive abilities.

After carrying out STEM-based learning, student scores experienced significant changes, namely, getting perfect results. So it can be said that the three students fulfil all the characteristics of cognitive abilities starting from remembering, understanding, applying, analyzing, evaluating, and creating. The previous statement was confirmed through unstructured interviews with the three students.

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