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MATHEMATICAL CREATIVE THINKING SKILL: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS

ABSTRACT

Someone with strong creative thinking skills will be able to solve problems effectively, particularly contextual problems in mathematics. Students rarely have creative thinking skills in the classroom. This occurs because of student errors. The goal of this study is to identify student errors in completing contextual problem-solving on integer operations. This is a qualitative study using an exploratory descriptive technique. The participants in this study were sixth-grade elementary school students. The research subjects were chosen on the teacher's recommendation, specifically students with good communication abilities, so that data on student errors in handling contextual problems on creative thinking skills can be easily examined and found. Tests and interviews were used as research instruments in this study. This study's methodologies included tests, interviews, and triangulation. The findings revealed that students lacked innovative thinking abilities and are unable to solve the problem appropriately, they failed to meet the four markers of creative thinking skill. According to the Action-Process-Object-Schema (APOS) theory, students' errors in solving contextual mathematical problems consist of four components: (1) interpretive errors, (2) concept understanding errors, (3) procedure errors, and (4) computing/technical errors. The findings of this study should be useful in constructing integer learning activities so that students do not make mistakes when tackling contextual problem-solving challenges on creative thinking skills. As a result, further study is needed to construct a mathematical learning model capable of improving mathematical creative thinking skills.

Keywords: Contextual problems, Creative thinking skills, Error Identification

1. INTRODUCTION

Creative thinking is essential in the twenty-first century, particularly in the field of education (Cooper, 2021; Konrad et al., 2021; Rahayuningsih et al., 2021). As one of the objectives of mathematics education, creative thinking in mathematics can assist students in understanding what is going on in their surroundings (Puspitasari et al., 2019; Yayuk et al., 2020). Furthermore, creative thinking plays a role in achieving meaningful learning (Ammaralikit & Chattiwat, 2020; Junaedi et al., 2021). As a result, teachers must foster creative thinking in classroom learning activities. Thinking creatively in mathematics is a key component for students in dealing with mathematical difficulties, as it allows students to consider new facts and ideas while solving mathematical problems (Ndiung et al., 2021; Puspitasari et al., 2019). The ability to think creatively in mathematics can also be described as a cognitive function that refers to the ability to develop mathematical ideas and concepts (Nwoke, 2021; Yayuk et al., 2020). Furthermore, the capacity to think creatively in mathematics is one of the features of higher-order thinking to generate new ideas from difficult problems (Ali et al., 2021; Junaedi et al., 2021). As a result, children must be able to think creatively in mathematics.

Many experts have presented indicators of creative thinking skills. A person with strong creative thinking abilities must meet four criteria: fluency, flexibility, originality, and elaboration(Jumadi et al., 2020; Rahayuningsih et al., 2021). Fluency is an ability to develop many types of ideas to solve difficulties. Flexibility refers to capacity to provide multiple solutions to a situation. Originality is capacity to articulate original thoughts that have not previously been considered. Elaboration refers to ability to develop ideas or thoughts and explain problems in detail. Therefore, fluency, Flexibility, Originality, and Elaboration are the indications of creative thinking capacity in this study, according to this explanation.

Solving mathematical problems, particularly contextual ones, is essential for students to develop creative thinking skills (Bintoro et al., 2021; Cho & Kim, 2020; Peltier & Peltier, 2020). This is because contextual problem-solving in mathematics can provide students with various ideas based on real-life experiences (Hawa et al., 2019; Nugroho et al., 2020). In addition, students will be able to solve contextual mathematical problems by correctly applying mathematical procedures or processes (Fonteles Furtado et al., 2019; Hunukumbure et al., 2021). On the other hand, students continue to make errors when dealing with contextual challenges related to creative thinking questions(Haghverdi & Wiest, 2016; Soneira, 2022). As a result, teachers must investigate student errors to incorporate classroom learning strategies properly.

Errors are a significant component of the conceptual knowledge and necessary in mathematics teaching (Barkai, 2021; Hu et al., 2022; Jones et al., 2020). As a result, teachers must be able to identify student errors through effective error analysis (Faizah et al., 2022; Peltier & Peltier, 2020). Therefore, students are encouraged to accomplish the activities assigned by the teacher (Kenney et al., 2020; Santia et al., 2019). Students commonly make interpretive errors, conceptual errors, procedural errors, and computational errors (calculations)(Haghverdi & Wiest, 2016; Kenney et al., 2020; Khalid & Embong, 2019; Peltier & Peltier, 2020). For example, when students turn variables into numbers, they make interpretation errors when translating or concluding a problem statement(Kshetree et al., 2021). This is usually tied to the number object (40). The conceptual error indicates a student's failure to comprehend a concept in the problem at hand and a failure to assess the link in a situation(Ammaralikit & Chattiwat, 2020; Köğce, 2022). Procedural errors occur when students fail to modify an algorithm despite understanding the studied principles (Ammaralikit & Chattiwat, 2020; Lien et al., 2021). Finally, computational error is connected to calculation errors made by students (Al-Jarf, 2022; Emara et al., 2021). These errors were caused by a variety of factors, including students' low disposition toward mathematics, a poor teaching framework, a poor teacher's ability to teach, students' perception of complex mathematics material, students' limited understanding of mathematics, and a lack of understanding in Students' higher order thinking capacity(Kshetree et al., 2021; Prayitno et al., 2022). As a result, assessing students' mental processes when solving mathematical assignments is vital.

The Action-Process-Object-Schema (APOS) hypothesis can be used to investigate students' mental processes when answering contextual challenges on creative thinking questions. The APOS theory is divided into four stages: action, process, object, and schema (Arnawa et al., 2021). In APOS theory, the action is carried out by an individual employing mathematical concepts in conjunction with an exact algorithm and directed by external stimuli during the action phase (Arnawa et al., 2021; Bintoro et al., 2021; Moon, 2019). APOS theory's process phase includes repetitive action and reflection to shift from relying on external signals to relying on internal cues (Arnawa et al., 2021; Boz-Yaman & Yiğit Koyunkaya, 2019; Tatira, 2021). The object phase of APOS theory focuses on recognizing that specific processes and transformations of action are regarded as a single thing to define shifts explicitly (Van Melle & Ferreira, 2022). Finally, the schema phase is a collection of predetermined ideas about actions, processes, objects, and schemas that are combined to build a mathematical structure for solving mathematical problems (Arnawa et al., 2021; Moru, 2020). APOS theory investigates what occurs in a person's mind when learning a mathematical concept and the successes and failures encountered when doing mathematical activities.

There have been numerous studies done on error analysis. Research (Didiş Kabar & Erbaş, 2021) shows that students make mistakes in the four presented model problems. According to Polya, research from (Sukoriyanto et al., 2016) reveals that students continue to make errors when tackling permutation and combination problems. According to (Sari et al., 2018), the most common inaccuracy in representational abilities is problem-solving employing arithmetic symbols. According to research from (Khalid & Embong, 2019), errors that arise when completing common problems using integer operations are misconceptions. According to research from (Ozrecberoglu et al., 2022), student accomplishment in answering non-routine math tasks is low since errors occur frequently. Finally, according to the findings of (Jones et al., 2020), students had difficulties solving problems involving fractions.

According to the previous research findings, academics have yet to examine the types of errors caused by students when answering contextual problems on mathematical creative thinking problems utilizing APOS theory. This encouraged the researchers to conduct a study in this area to uncover and identify errors made by elementary school students when solving contextual problems that required creative thinking skills using APOS theory. By using APOS theory, this study seeks to identify students' errors in solving contextual difficulties on creative thinking topics. The researchers chose the APOS theory because it may describe students' mental actions in constructing mathematical concepts. Furthermore, this initial identification is critical for shaping students' creative thinking skills so that relevant learning models based on study findings may be constructed.

2. METHODS

2.1 Research Design

The exploratory descriptive approach is used in this study's qualitative investigation. When students complete a written test on contextual mathematical problems, this approach aims to collect verbal data from their answers. In this study, open-ended questions were used in interviews. This is done to confirm the research subjects' responses. The issues addressed in this study include students' failures in answering contextual mathematical problems on creative thinking skills using the APOS theory (Action-Process-Object-Schema).

2. 2 Research Subject

The participants in this study were all sixth-grade students from one of Cirebon Regency's state elementary schools. Because not all students were chosen as participants, the research subjects were chosen using a purposive sample technique. Fifty students have studied integer material. In the allotted time, students must solve four contextual mathematical problems that can test their creative thinking skills. Based on creative thinking indications, all response papers were collected and examined. Students who performed exceptionally well were not chosen as subjects. On the other hand, students who answered the sheet with errors in solving contextual problems, including numerical material, were considered research subjects. The research subjects were chosen on the teacher's recommendation, specifically students with good communication abilities, so that data on student errors in handling contextual problems on creative thinking skills can be easily examined and found. Two students were chosen for interviews based on the teacher's recommendation.

2.3. Research Instrument

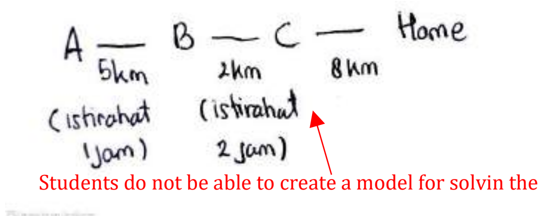
Tests and interviews were used as research instruments in this study. The main objective of the test is to identify numerous faults made by students. The test consisted of four contextual problems based on markers of students' creative thinking ability. The contextual problem indicators are based on four characteristics of creative thinking abilities (Kshetree et al., 2021): fluency, flexibility, originality, and elaboration. The interview was conducted to gather more information from the student's written response sheets. The interview format was unstructured, so the researcher did not plan the questions to ask the study subject. Instead, students were expected to provide the reasoning for their responses throughout this interview. The interview questions were based on the answer sheets of the students that were interviewed. Finally, the researcher confirmed the test answers acquired from the interviewed students.

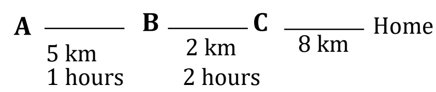
2.4. Data Analysis

Initially, 40 students were asked to take a test consisting of four essay-style questions about contextual difficulties related to mathematics creative thinking skills. The students have 40 minutes to finish the test and submit an answer sheet. The researchers then select the students' answers based on the assumption of errors committed by the students. The researchers then collaborated with the class teacher to pick two students for interviews. After selecting research subjects, interviews were conducted to corroborate further responses from the students' written responses. Interviews lasted 45 to 60 minutes, and all of them were recorded. APOS theory was used to conduct interviews for this study to learn more about the errors' students made when tackling challenges involving mathematical creativity in context. The researchers then independently assessed the outcomes of the student interviews. The next step was data triangulation, which was accomplished by comparing the results of the written test of contextual problems on the capacity to think creatively in mathematical problems with the results of interviews conducted between researchers and students. The researchers then drew findings based on the triangulation results.

3. RESULTS AND DISCUSSION

According to the Fluency indicator, Figure 1 shows the findings from the contextual problem-solving test of students' critical thinking skills. Figure 1(a) depicts students' responses in Indonesian, and Figure 1(b) depicts students' responses in English. The test results demonstrated that students could not meet the Fluency indicator when answering contextual mathematical problems since they could not provide various solutions. This occurred because students did not comprehend how to solve problems, causing them to make mistakes. It was most likely due to students' inability to comprehend the questions raised in these tasks. As a result, interviews must be conducted to determine students' errors in solving contextual problems related to questions on the Fluency indicator utilizing APOS theory.



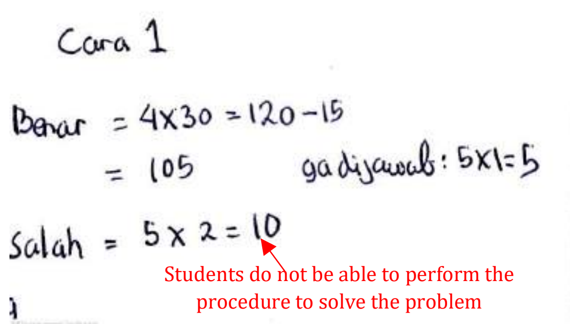


(a) **(b)**

Figure 1 Students's answer on the Fluency indicator (a) Indonesian and (b) English

The results of the interviews revealed that students made an interpretation error. It was shown that students did not write down what they know and what was requested in the response. Furthermore, students drew incorrect route drawings based on the problems in the questions. Students could convert daily language into mathematical language, but they did not understand the meaning of the questions.

Figure 2 shows the results of the contextual problem-solving test of students' creative thinking skills, measured by the Flexibility indicator. Figure 2(a) depicts students' responses in Indonesian, while Figure 2(b) depicts students' responses in English. The test findings demonstrate that students did not meet the Flexibility indicator for solving contextual mathematical problems since they were unable to propose various solutions or approaches to the topic at hand. Furthermore, they cannot present more than one approach or procedure for working on questions. That was most likely due to students' inability to understand the questions raised in answering these issues, causing them to make mistakes. As a result, interviews must be conducted to identify student errors in solving contextual problems using APOS theory.



Rule 1
True = 4x30=120-15 =105
Wrong : 5 x 2 = 10

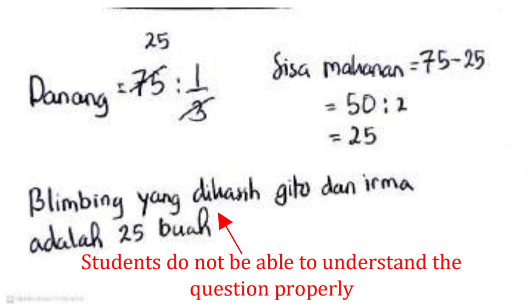
Not Answer = 5 x 1 = 5

(a) **(b)**

Figure 2 Students' answer on the Flexibility indicators (a) Indonesian and (b) English

The interviews revealed that students made an interpretation error. It was shown that students did not write down what they knew and what was requested in the response. They could convert daily language into mathematical language, but they did not understand the significance of the questions. Students made mistakes on the concept too. It was proved by the student applying the operating formula on integers. Furthermore, students make incorrect choices for the numbers that are operated in the problem. Students also made procedural errors because they could not fully explain the answers, and computational errors as well. All of the errors were proven by the answers of the problem.

Figure 3 illustrates the outcomes of the contextual problem-solving test of students' creative thinking skills, as measured by the Originality indicator. Figure 3(a) depicts students' responses in Indonesian, whereas Figure 3(b) depicts students' responses in English. The test findings demonstrate that students were unable to meet the Originality indicator when solving contextual mathematical problems because they were unable to convey fresh concepts that had not previously been considered. This was due to students' incapacity to propose original ideas and their inability to understand the questions in answering these problems. Using APOS theory, interviews were conducted to identify student errors in solving contextual problems related to questions on the Originality indicator.



Danang = 75 : 1/3

Food left = 75 – 25
= 50 : 2
= 25

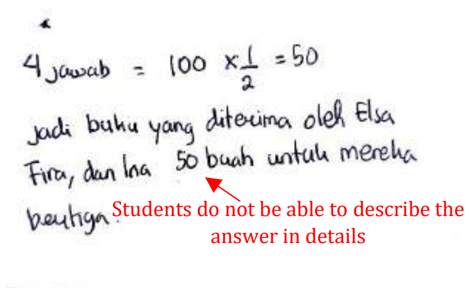
Startfruits given to Gito and Irma are 25.

(a) **(b)**

Figure 3 Students answers on the originality indicator (a) Indonesian and (b) English

The results of the interviews revealed that students erred in their understanding. They did not write down what they knew and did not write down what was requested in the response. Students could convert daily language into mathematical language, but they did not understand the meaning of the questions. Students misunderstood the concept as well. It is proven that students were incorrect in using formulas for fractional operations and integer arithmetic operations. Furthermore, students made incorrect choices for the numbers that were operated in the problem. Students also made procedural errors because they could not fully explain the answers they obtained and made computational errors. Finally, it has been proven that students were incorrect in their final answers.

Figure 4 shows the results of the contextual problem-solving exam of students' creative thinking skills, as measured by the Elaboration indicator. Figure 4(a) depicts students' responses in Indonesian, whereas Figure 4(b) depicts students' responses in English. The exam results demonstrated that students could not meet the Elaboration indicator while answering contextual mathematical problems because they could not develop thoughts or ideas and explain the problems that had been solved in detail. This occurred due to students' failure to describe their answers in detail, causing them to make mistakes. As a result, interviews must be conducted utilizing APOS theory to identify student faults in solving contextual problems related to questions on the Elaboration indicator.



Answer: 100 x ½

= 50

Then, books received by Elsa, Fira, and Lea approximately 50 books for all of them.

(a) **(b)**

Figure 4 Students answers on Elaboration indicator (a) Indonesian and (b) English

The interviews revealed that students made a mistake in their understanding. It was shown that students did not write down what they knew and did not write down what was requested in the response. Students could convert daily language into mathematical language, but they did not understand the significance of the questions. Students made mistakes on the concept too. It was proved by the student applying the operating formula on integers. Furthermore, students make incorrect choices for the numbers that are operated in the problem. Students also made procedural errors because they could not fully explain the answers they obtained, and they made computational errors as well.

Students with low mathematical creative thinking abilities were chosen as research subjects. This is because the students could not answer the four questions presented in contextual situations using the four indications of creative thinking abilities. Students' inability to attain indications of creative thinking skills in contextual mathematical problems was driven by a lack of familiarity with these types of questions (Ilhan &

Akin, 2022; Kolar & Hodnik, 2021). In addition, students were only accustomed to challenges that did not necessitate using creative thinking skills. As a result, students must get acquainted with contextual difficulties that necessitate applying creative thinking skills (Rafiee & Abbasian-Naghneh, 2020; Yustina et al., 2022).

To handle contextual difficulties, students' creative thinking skills must be developed. One approach is to employ a learning model that requires students to participate in their learning in class. Material delivery must also focus on results, and problems must provide students with challenges relating to contextual problem. This is consistent with the research(Balakrishnan, 2022), which suggests that one strategy to promote creative thinking skills in elementary school students is to use teaching strategies that require students to be active in classroom learning and acquaint them with addressing complex challenges connected to learning. Furthermore, teachers must provide immediate supportive feedback to students that allows students to actively find their answers so that students do not struggle to solve contextual problems(Kim et al., 2022).

In sixth-grade elementary school, two students with low creative thinking skill make mistakes when answering contextual mathematical problems. Students' common errors in solving contextual problems requiring creative thinking abilities can be divided into four categories: interpretation errors, conceptual errors, procedural errors, and computational/technical errors. Students' interpretation errors occur when they fail to understand the topic or problem in the given context. They are unable to grasp the significance of the questions posed to them. Based on the four questions given, students could not put down what was known and what was asked in the question, causing students to misinterpret the meaning. Furthermore, in question one, the student incorrectly described the sketch of the route image based on the difficulty of the problem. Students created a route using only straight lines, although the question stated that the path should return to the starting position because Budi returns to the origin. Students were also incorrect in their findings in response to the inquiry. Students made errors in responding correctly to the presented contextual difficulties based on the four questions. Students also did not fully comprehend the questions presented. This was due to students' inability to define or comprehend sketch drawings in a specific topic (Özdemir & Dede, 2022).

Students committed conceptual errors, such as incorrectly applying the formula for arithmetic operations with mixed integers. In question number two, students did arithmetic operations on integers without considering which rule was stronger between addition, subtraction, multiplication, and division operations causing them to perform incorrectly. Students also misunderstood the division process of numbers in question number two. In response to question number two, the students answered $75 \div \frac{1}{3}$. P In this question, the students crossed out the numbers 75 and 3. It was shown that the students had a wrong idea of division and multiplication operations. The correct notion was $75 \div \frac{1}{3} = 75 \times 3$. Additionally, students choose the incorrect number to operate on in the problem. This was because students did not comprehend what was being requested in the problem, causing numbers that did not need to be operated to become operational (Joung & Kim, 2022).

Based on the four questions, students experienced errors in choosing the numbers to operate in the questions. This is due to students' failure to read the questions carefully, resulting in students misunderstanding what the questions signify. This demonstrates that students' knowledge of mathematical concepts remains low. This is reinforced by (Karakuş et al., 2022), which indicates that their conceptual comprehension is poor when students answer specific mathematical problems. As a result, students make conceptual errors. The finding is supported by study (Tooher & Johnson, 2020), which found that students struggle to grasp particular mathematical topics if they do not understand the ideas relevant to the studied issues. Students will make mistakes when answering problems, particularly contextual ones. Conceptual errors can also develop as a result of prior knowledge. This is consistent with the findings of a study (Jarrah et al., 2022), which found that students' conceptual errors are also caused by prior mathematical learning. For example, students are unable to comprehend integer concepts since merely memorize integer formulas without applying the concept and how to apply them. As a result, students struggle to gain a correct and comprehensive comprehension of a concept (Barbieri & Booth, 2020).

Students made procedural errors, including failing to explain the steps on the answer sheet adequately. Students only mentioned the outcome in question number one. Students were unable to explain the methods taken to acquire the answer from number one. Then, on problems 2 and 3, students could explain the phases of the response, but only partially because the final answers were incorrect. The students could not clarify their answers to question four because they misinterpreted the significance of the questions. Furthermore, students were incorrect in concluding the results of the given problem. This was demonstrated by question five, in which students assumed that the books delivered to Elsa, Fira, and Ina were the same as 50 books. The problem fails to indicate that Elsa, Fira, and Ina's book distribution was the same amount. As a result, students did not understand the significance of the problem, and their conclusions were incorrect. Students were also incorrect in executing integer operations when solving problems, even though they had reached the proper conclusions. Therefore, students need to apply all the principles required to answer the problem to avoid making errors in determining the outcome (Hu et al., 2022). Students must be able to present valid mathematical reasons, draw conclusions, and develop generalizations in order to solve a specific mathematical problem(Köğce, 2022).

Students' technical or computational errors happened during the calculation procedure. For example, it could be discovered in the procedure of multiplying integers in problem number two. The student carries out the operation $6 \times (-1) = -5$. The conclusions of these calculations were incorrect; hence students' final answers to the problems were incorrect. This was consistent with the study's findings(Khalid & Embong, 2019), which found that most students had broad misconceptions regarding integer operations, such as the multiplication of positive and negative integers. Errors in dividing integers by fractions occured because students were less attentive while performing operations. As a result, a technical error happened. For example, in question three, students completed the operation $75 \div \frac{1}{3} = 25$. The outcomes of these calculations were inaccurate, causing students to conclude the final answer to the presented questions incorrectly. According to the study, the most common mistakes students make in the operation of dividing integers are those who are negligent in using the methods of the problems supplied (Üzel, 2018). As a result, students must have strong fundamental mathematical problem-solving abilities to solve contextual mathematical problems (Sternberg et al., 2021). This is essential to ensure that students' mistakes do not reoccur.

According to the findings, sixth-grade students were still in the action stage of the APOS theory. This occurs because students lack an APOS conceptual structure, causing them to make errors when faced with contextual mathematical problems. For example, students have trouble implementing integer operations due to a lack of conceptual structure connected to the process, object, and schema stages(Kshetree et al., 2021). This demonstrates that students cannot manage the application of theorems and formulas required for specific mathematical problems. Based on the APOS theory analysis findings, students have difficulties understanding the idea of operations on numbers. This is because when the students were at the previous level, they could not understand the notion of operations on integers, causing them to make errors in solving the problems presented. Students only memorize formulas, so they struggle when they learn about the idea of operations on integers. In addition, students lack experience understanding integer operations, do not fully understand the concept of integer operations, and have minimal prior knowledge of integer operations at the previous level. As a result, teachers must have an effective strategy to identify student errors. One technique for reducing student errors in handling contextual problems is to hold open discussions focusing on efforts to overcome student errors during the learning process (Ilhan & Akin, 2022).

Assessing and analyzing students' errors in completing contextual problems on creative thinking skills is considered an essential tool for learning(Rahayuningsih et al., 2021). Furthermore, it is indicated that to overcome cognitive obstacles in solving difficulties presented in learning mathematics, and students must have a positive mindset and optimal thinking activities that activate prior knowledge and experience in solving specific problems. Since students in different courses differ in their capacities for creative thought, the understanding of particular students should be considered while designing a teacher's thinking activity(Jumadi et al., 2020).

These findings suggest that teachers should appropriately prepare students on the classroom's procedural and conceptual parts of mathematics. Both features are critical in comprehending mathematical material (Barbieri & Booth, 2020). Identifying students' errors in addressing contextual mathematical problem and the skill to think creatively on integer operations has helped teachers recognize students' shortcomings. This will assist the teacher in preparing classroom activities and addressing errors that occur. Students' errors are caused by a lack of creative thinking skills when tackling contextual mathematical problems. According to (Tooher & Johnson, 2020), a student with low notions in creative thinking skills will make mistakes in solving the problem. Therefore, students' skill to think creatively must be developed so that similar errors will not occur again. After improving their creative thinking skills, students will develop their own formulas or principles for solving mathematical problems. According to the research, strengthening mathematical creative thinking skills would allow students to pay attention to all components required to assist in solving mathematical problems, allowing them to find formulas or rules on their own (Foster, 2021).

4. CONCLUSSION

Based on the research results and discussion, it concludes that the students chosen for the study had low creative thinking skills in solving contextual problem-solving difficulties in mathematics. This is due to students' inability to meet the four creative thinking markers of Fluency, Flexibility, Originality, and Elaboration. This incapacity was caused by errors made by students when tackling contextual problem-solving difficulties using creative thinking skills. According to the APOS theory, student errors include (1) Misinterpretation errors: incorrectly converting the questions into mathematical language/symbols and misinterpreting the given questions; (2) Conceptual errors: students misused formulas while counting fractions and integers. Furthermore, students made wrong choices for the numbers that were operated in the problem; (3) Procedural error: the student improperly concluded the question. This was because students failed to pay attention to what was asked in the question and were incorrect in carrying out the processes to solve the problem because students were unable to explain the solutions received. (4) Technical/computing errors: students made errors in computations involving integer operations, and students' final answers to the questions they worked on were incorrect.

Future study should lead to the development of new learning models capable of improving mathematical creative thinking skills. This is significant because research shows that kids with strong creative thinking skills adapt fast to new issues. On the other hand, students who lack creative thinking skills will have difficulty solving an issue. Future research should investigate how students think while tackling contextual problems in mathematics. Identifying students' cognitive processes will help them better grasp because they take a particular approach to problem-solving. When teachers understand their students' thought processes, they can identify students' challenges quickly when solving mathematical problems. As a result, the teacher can modify the learning paradigm for the next meeting.

REFERENCES

Al-Jarf, R. (2022). Student-Interpreters' Foreign Proper Noun Pronunciation Errors in English-Arabic and Arabic-English Media Discourse Interpreting. *International Journal of Translation and Interpretation Studies*, *2*(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature Review : Mathematical Creative Thinking Ability , and Students ' Self Regulated Learning to Use an Open Ended Approach. *Malikussaleh Journal of Mathematics Learning*, *4*(1), 52–61.

Ammaralikit, A., & Chattiwat, W. (2020). Effects of Business Reading Model on Thai Learners' Reading and Creative Thinking Abilities. *English Language Teaching*, *13*(5), 191. https://doi.org/10.5539/elt.v13n5p191

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? *International Journal of Instruction*, *14*(3), 175–186. https://doi.org/10.29333/iji.2021.14310a

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: a study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education*, *32*(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on display: Incorrect examples refine equation solving and algebraic feature knowledge. *Applied Cognitive Psychology*, *34*(4), 862–878. https://doi.org/10.1002/acp.3663

Barkai, R. (2021). Using cases as a means to discuss errors in mathematics teacher education. *Education Sciences*, *11*(10). https://doi.org/10.3390/educsci11100575

Bintoro, H. S., Walid, & Mulyono. (2021). The Spatial Thinking Process of the Field-Independent Students based on Action-Process-Object-Schema Theor. *European Journal of Educational Research*, *10*(4), 1807–1823.

Boz-Yaman, B., & Yiğit Koyunkaya, M. (2019). Examination of Pre-service Mathematics Teachers' Mental Constructions of Function Transformation. *Acta Didactica Napocensia*, *12*(1), 33–56. https://doi.org/10.24193/adn.12.1.3

Cho, M. K., & Kim, M. K. (2020). Investigating elementary students' problem solving and teacher scaffolding in

solving an Ill-structured problem. *International Journal of Education in Mathematics, Science and Technology*, *8*(4), 274–289. https://doi.org/10.46328/IJEMST.V8I4.1148
Cooper, A. A. (2021). Incorporating Critical and Creative Thinking in a Transitions Course. *Primus*, *31*(9), 995–1006. https://doi.org/10.1080/10511970.2020.1805659
Didiş Kabar, M. G., & Erbaş, A. K. (2021). Pre-service secondary mathematics teachers' anticipation and identification of students' thinking in the context of modelling problems. *International Journal of Mathematical Education in Science and Technology*, *52*(2), 208–236. https://doi.org/10.1080/0020739X.2019.1670368
Emara, M., Hutchins, N. M., Grover, S., Snyder, C., & Biswas, G. (2021). Examining student regulation of collaborative, computational, problem-solving processes in openended learning environments. *Journal of Learning Analytics*, *8*(1), 49–74. https://doi.org/10.18608/JLA.2021.7230
Faizah, S., Nusantara, T., Sudirman, & Rahardi, R. (2022). Constructing Students' Thinking Process through Assimilation and Accommodation Framework. *Mathematics Teaching-Research Journal*, *14*(1), 253–269.
Fonteles Furtado, P. G., Hirashima, T., Hayashi, Y., & Maeda, K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. *Research and Practice in Technology Enhanced Learning*, *14*(1), 1–18. https://doi.org/10.1186/s41039-019-0096-1
Foster, M. K. (2021). Design Thinking: A Creative Approach to Problem Solving. *Management Teaching Review*, *6*(2), 123–140. https://doi.org/10.1177/2379298119871468
Haghverdi, M., & Wiest, L. R. (2016). The Effect of Contextual and Conceptual Rewording on Mathematical Problem- Solving Performance. *The Mathematics Educator*, *25*(1), 56–73.
Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient approach to teach literary sociology. *International Journal of Instruction*, *12*(1), 283–298. https://doi.org/10.29333/iji.2019.12119a
Hu, Q., Son, J. W., & Hodge, L. (2022). Algebra Teachers' Interpretation and Responses to Student Errors in Solving Quadratic Equations. *International Journal of Science and Mathematics Education*, *20*(3), 637–657. https://doi.org/10.1007/s10763-021-10166-1
Hunukumbure, A. D., Horner, P. J., Fox, J., & Thakerar, V. (2021). An online discussion between students and teachers: a way forward for meaningful teacher feedback? *BMC Medical Education*, *21*(1), 1–9. https://doi.org/10.1186/s12909-021-02730-8
Ilhan, A., & Akin, M. F. (2022). Analysis of Contextual Problem Solutions, Mathematical Sentences, and Misconceptions of Pre-Service Mathematics Teachers. *International Electronic Journal of Mathematics Education*, *17*(1), em0666. https://doi.org/10.29333/iejme/11470
Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(6). https://doi.org/10.29333/ejmste/12070
Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. *School Science and Mathematics*, *120*(4), 232–243. https://doi.org/10.1111/ssm.12402
Joung, E., & Kim, Y. R. (2022). Identifying Preservice Teachers' Concept-based and Procedure-based Error patterns in Multiplying and Dividing Decimals. *International Journal of Education in Mathematics, Science and Technology*, *10*(3), 549–567. https://doi.org/10.46328/ijemst.2227
Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE)*, *9*(2), 415–420. https://doi.org/10.11591/ijere.v9i2.20531
Junaedi, Y., Wahyudin, & Juandi, D. (2021). Mathematical creative thinking ability of junior high school students' on polyhedron. *Journal of Physics: Conference Series*, *1806*(1), 36–45. https://doi.org/10.1088/1742-6596/1806/1/012069
Karakuş, D., Özkaya, M., & Konyaliglu, A. C. (2022). Geogebra in the Correction and Understanding of Errors Regarding the Concept of Asymptote. *Shanlax International Journal of Education*, *10*(2), 67–79. https://doi.org/10.34293/education.v10i2.4400
Kenney, R., An, T., Kim, S. H., Uhan, N. A., Yi, J. S., & Shamsul, A. (2020). Linear Programming Models: Identifying Common Errors in Engineering Students' Work with Complex Word Problems. *International Journal of Science and Mathematics Education*, *18*(4), 635–655. https://doi.org/10.1007/s10763-019-09980-5
Khalid, M., & Embong, Z. (2019). Sources and Possible Causes of Errors and Misconceptions in Operations of Integers. *International Electronic Journal of Mathematics Education*, *15*(2).

https://doi.org/10.29333/iejme/6265
Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of Scaffolding on Information Literacy and Argumentation Skills in Virtual Field Trips and Problem-Based Learning for Scientific Problem Solving. *International Journal of Science and Mathematics Education*, *20*(2), 215–236. https://doi.org/10.1007/s10763-020-10145-y
Köğce, D. (2022). Examination of Mathematical Errors and Mistakes in Calculus Course. *Educational Policy Analysis and Strategic Research*, *17*(1), 295–311. https://doi.org/10.29329/epasr.2022.248.15
Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. *European Journal of Educational Research*, *10*(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467
Konrad, M., Editor, A., & Smith, J. E. (2021). *Creative Self-Efficacy : An Essential Transition Skill for Students With Learning Disabilities*. https://doi.org/10.1177/10534512211024938
Kshetree, M. P., Acharya, B. R., Khanal, B., & Panthi, R. K. (2021). Eighth Grade Students' Misconceptions and Errors in Mathematics Learning in Nepal. *European Journal of Educational Research*, *10*(4), 1907–1918.
Lien, N. T. N., Khuyen, N. T. T., Tho, N. T., Hoa, N. N., Hanh, N. T., Tho, C. C., Hai, T. D., & Van Bien, N. (2021). Teachers' feelings of safeness in school-family-community partnerships: Motivations for sustainable development in moral education. *International Journal of Evaluation and Research in Education*, *10*(1), 97–107. https://doi.org/10.11591/ijere.v10i1.20798
Moon, K. (2019). PRESERVICE TEACHERS? UNDERSTANDING OF TWO-VARIABLE INEQUALITIES: APOS THEORY. *Proceedings of the 41st Annual Meeting of PME-NA*, 686–694.
Moru, E. K. (2020). An APOS Analysis of University Students' Understanding of Derivatives: A Lesotho Case Study. *African Journal of Research in Mathematics, Science and Technology Education*, *0*(0), 1–14. https://doi.org/10.1080/18117295.2020.1821500
Ndiung, S., Sariyasa, Jehadus, E., & Apsar, R. A. (2021). The Effect of Treffinger Creative Learning Model with the Use RME Principles on Creative Thinking Skill and Mathematics Learning Outcome. *International Journal of Instruction*, *14*(2), 873–888.
Nugroho, A. A., Nizarudin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students ' creative thinking in the use of representations in solving mathematical problems based on cognitive style. *Journal of Research and Advances in Mathematics Education*, *5*(2), 202–217. https://doi.org/10.23917/jramathedu.v5i2.9983
Nwoke, B. L. (2021). Enhancing primary school pupils ' mathematics creative ability through activity based learning approach. *Malikussaleh Journal of Mathematics Learning (MJML)*, *4*(2), 70–76.
Özdemir, E., & Dede, E. (2022). INVESTIGATION OF THE WAYS PROSPECTIVE MATHEMATICS TEACHERS RESPOND TO STUDENTS ' ERRORS : AN EXAMPLE OF OF THE EQUAL SIGN. *International Online Journal of Education and Teaching (IOJET)*, *9*(2), 723–739.
Ozrecberoglu, N., Aydın, S., & Aydın, O. (2022). Students' Skills In Solving Non-Routine Mathematical Problems. *Education Quarterly Reviews*, *5*(2), 446–461. https://doi.org/10.31014/aior.1993.05.02.504
Peltier, C., & Peltier, T. K. (2020). Mining Instruction From Student Mistakes: Conducting an Error Analysis for Mathematical Problem Solving. *Beyond Behavior*, *29*(3), 141–151. https://doi.org/10.1177/1074295620903050
Prayitno, A. T., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2022). Identification of graph thinking in solving mathematical problems naturally. *Participatory Educational Research*, *9*(2), 118–135. https://doi.org/10.17275/per.22.32.9.2
Puspitasari, L., In, A., & Syaifuddin, M. (2019). Analysis of Students ' Creative Thinking in Solving Arithmetic Problems. *INTERNATIONAL ELECTRONIC JOURNAL OF MATHEMATICS EDUCATION*, *14*(1), 49–60.
Rafiee, M., & Abbasian-Naghneh, S. (2020). Willingness to Write (WTW): Development of a model in EFL writing classrooms. *Cogent Education*, *7*(1), 0–16. https://doi.org/10.1080/2331186X.2020.1847710
Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. *Participatory Educational Research*, *8*(3), 285–299. https://doi.org/10.17275/per.21.66.8.3
Santia, I., Purwanto, Sutawidjadja, A., Sudirman, & Subanji. (2019). Exploring mathematical representations in solving ill-structured problems: The case of quadratic function. *Journal on Mathematics Education*, *10*(3), 365–378. https://doi.org/10.22342/jme.10.3.7600.365-378
Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with react strategy in solving the problems of mathematical representation ability. *Journal on Mathematics Education*, *9*(1), 121–128. https://doi.org/10.22342/jme.9.1.4378.121-128
Soneira, C. (2022). The Use of Representations when Solving Algebra Word Problems and the Sources of

Solution Errors. *International Journal of Science and Mathematics Education*, *20*(5), 1037–1056. https://doi.org/10.1007/s10763-021-10181-2

Sternberg, R. J., Glaveanu, V., Karami, S., Kaufman, J. C., Phillipson, S. N., & Preiss, D. D. (2021). Meta-intelligence: understanding, control, and interactivity between creative, analytical, practical, and wisdom-based approaches in problem solving. *Journal of Intelligence*, *9*(2). https://doi.org/10.3390/jintelligence9020019

Sukoriyanto, S., Nusantara, T., Subanji, S., & Chandra, T. D. (2016). Students' Errors in Solving the Permutation and Combination Problems Based on Problem Solving Steps of Polya. *International Education Studies*, *9*(2), 11. https://doi.org/10.5539/ies.v9n2p11

Tatira, B. (2021). Mathematics Education Students' Understanding of Binomial Series Expansion Based on the APOS Theory. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(12), 1–13. https://doi.org/10.29333/EJMSTE/11287

Tooher, H., & Johnson, P. (2020). The role of analogies and anchors in addressing students' misconceptions with algebraic equations. *Issues in Educational Research*, *30*(2), 756–781.

Üzel, D. (2018). Investigation of misconceptions and errors about division operation in fractions. *Universal Journal of Educational Research*, *6*(11), 2656–2662. https://doi.org/10.13189/ujer.2018.061131

Van Melle, J., & Ferreira, M. (2022). Developing Students' Intercultural Sensitivity at the Home Campus: An Innovative Approach Using the Theory of the Creative Action Methodology Pedagogy. *Teaching and Learning Inquiry*, *10*, 1–23. https://doi.org/10.20343/TEACHLEARNINQU.10.12

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yustina, Mahadi, I., Ariska, D., Arnentis, & Darmadi. (2022). The Effect of E-Learning Based on the Problem-Based Learning Model on Students' Creative Thinking Skills During the Covid-19 Pandemic. *International Journal of Instruction*, *15*(2), 329–348. https://doi.org/10.29333/iji.2022.15219a

Bukti Konfirmasi Review dan Hasil Review Pertama

tanggal 24 Oktober 2024

Khoerul Umam <khoerul.umam@uhamka.ac.id>

[HASSS] Editor Decision - Accept with Minor Revisions

7 messages

Korakoch Attaviriyanupap via Thai Journals Online (ThaiJO) <admin@tci-thaijo.org> Thu, Oct 24, 2024 at 8:12 AM
Reply-To: Korakoch Attaviriyanupap <hasss.editor@su.ac.th>
To: Khoerul Umam <khoerul.umam@uhamka.ac.id>, Ardi Dwi Susandi <ardi.official@ecampus.ut.ac.id>, Muhammad Irfan <irvahn@gmail.com>, Mohd Isha Bin Awang <isha@uum.my.edu>, Eka Nana Susanti <eka_nana@uhamka.ac.id>, Supandi <supandi@uhamka.ac.id>

Dear Khoerul Umam, Ardi Dwi Susandi, Muhammad Irfan, Mohd Isha Bin Awang, Eka Nana Susanti, Supandi,

We have reached a decision regarding your submission to Humanities, Arts and Social Sciences Studies, "MATHEMATICAL CREATIVE THINKING SKILL: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS ".

Our decision is: **Accept with minor revisions**.

For your guidance, reviewers' comments are appended below. Please submit an itemized list of changes which have been made in response to the reviewer's comments/suggestions or a rebuttal of why a particular comment/suggestion was not acted upon. Changes to the manuscript should be made in **RED** so they are distinct from the original text. In order to expedite publication of the manuscript, we would appreciate receiving the revised manuscript by **3 weeks.**

Thank you for your co-operation. We look forward to receiving the revised manuscript.

Reviewer E:
Recommendation:

The subject addressed in this article is worthy of investigation.

1

The information presented was new.

1

The conclusions were supported by the data.

1

Type of manuscript:

My Overall Recommendation:

The manuscript is appropriate for the journal

The subject addressed in this article is worthy of investigation

The abstract is clear and comprehensive

The organization of the manuscript is appropriate

The conclusions are supported by the data and the analysis

Figures, tables and supplementary data are appropriate

The paper is written in good English

Enter feedback on the manuscript in the text boxes below.

Comments to Author:

Reviewer F:
Recommendation: Revisions Required

The subject addressed in this article is worthy of investigation.

3

The information presented was new.

4

The conclusions were supported by the data.

8

Type of manuscript:

Research article

My Overall Recommendation:

Accept with minor revisions

The manuscript is appropriate for the journal

Agree

The subject addressed in this article is worthy of investigation

Agree

The abstract is clear and comprehensive

Agree

The organization of the manuscript is appropriate

Neutral

The conclusions are supported by the data and the analysis

Neutral

Figures, tables and supplementary data are appropriate

Agree

The paper is written in good English

Agree

Enter feedback on the manuscript in the text boxes below.

Comments to Author:

The manuscript should be revised as the followings:

- The introduction (topic 1) should elaborate more about the relations and connections among Math Creative Thinking Skill, APOS Theory, and Errors in problem solving. This will make clear about conceptual framework and design of this research.

- The conclusions (topic 4) cannot overclaim that low creative thinking skill found in this research was caused by errors made by students when solving contextual problems. The research methodology was not about cause and effects or antecedent and consequences.

- The research instruments, especially, constructs of the tests, were not clear enough to ensure the measures of faults in solving problems that related to Math Creative Thinking Skill, should add more details (topic 2.3).

Kind regards,
Editorial team
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6 Rachamakha Nai Rd., Amphoe Muang, Nakhon Pathom 73000, Thailand.

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2 attachments

H-[HASSS_2024_0314] Correction report.docx
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E-[HASSS_2024_0314] Reviewer Report.docx
19K

Khoerul Umam <khoerul.umam@uhamka.ac.id> Thu, Oct 24, 2024 at 8:15 AM
To: "Irfan Muh." <irvahn@gmail.com>

[Quoted text hidden]

2 attachments

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Bukti konfirmasi submit revisi Pertama, respon kepada reviewer, dan artikel yang diresubmit

7 November 2024

Khoerul Umam <khoerul.umam@uhamka.ac.id>

[HASSS] Editor Decision - Accept with Minor Revisions

Khoerul Umam <khoerul.umam@uhamka.ac.id> Thu, Nov 7, 2024 at 4:29 PM
To: Korakoch Attaviriyanupap <hasss.editor@su.ac.th>

Dear Editor,

We have submitted our revised paper along with the required supporting documents. Additionally, we would like to update the email address for one of our authors to **muhammadirfan@uny.ac.id**.

The corrections have been detailed in the attached submission form.

Thank you for your attention and assistance.

Best regards,
Khoerul Umam

[Quoted text hidden]

3 attachments

Correction report.pdf
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[HASSS_2024_0314]+Submission+Form.docx
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Manuscript without author.docx
230K

Correction page

Ref: HASSS_2024_0314

Title: "Mathematical Creative Thinking Skill: Using Apos Theory To Identify Student Errors In Solving Contextual Problems"

Reviewer's Comments	Corrections made | (Please also specify page(s) and line(s) of the corrections done)	Reasons why the comments were not acted upon
- The introduction (topic 1) should elaborate more about the relations and connections among Math Creative Thinking Skill, APOS Theory, and Errors in problem solving. This will make clear about conceptual framework and design of this research.	Page 2, Line 84 – 93	
The research instruments, especially, constructs of the tests, were not clear enough to ensure the measures of faults in solving problems that related to Math Creative Thinking Skill, should add more details (topic 2.3).	Page 3, Line 119 – 128	
The conclusions (topic 4) cannot overclaim that low creative thinking skill found in this research was caused by errors made by students when solving contextual problems.	Page 8, Line 335-336	
The research methodology was not about cause and effects or antecedent and consequences.	Page 9, line 149-159.	

Sign..

(Khoerul Umam)

Date Nov / 7 / 2024

MATHEMATICAL CREATIVE THINKING SKILL: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS

ABSTRACT

Individuals with strong creative thinking abilities are particularly adept at effectively addressing mathematical contextual problems. However, it is common for students to need more creative thinking skills within the classroom setting, often due to various errors made by students themselves. This study aims to identify students' specific errors when attempting to solve contextual problems related to integer operations. Utilizing a qualitative approach, this research employs an exploratory, descriptive technique and focuses on sixth-grade elementary school students. Participants were selected based on the teacher's recommendations, specifically targeting students with strong communications skills to comprehensively examine their errors in dealing with contextual problems and their creative thinking skills. The research utilized tests and interviews as instruments for data collection, incorporating methodologies such as testing, interviewing, and triangulation. The results indicate a significant deficiency in students' innovative thinking skills, rendering them unable to solve problems effectively, which leads to an inability to meet the four criteria of creative thinking. Based on the Action-Process-Objects-Scheme (APOS) theory, the identified errors in students' approaches to contextual mathematical problems can be categorize into four types: (1) interpretive errors, (2) errors in conceptual understanding, (3) procedural errors, and (4) computational or technical errors. The insight gained from this study can inform the design of integer learning activities, helping minimize contextual problem-solving mistakes that require creative thinking skills. Consequently, further research is essential to develop a mathematical learning model that can enhance students' mathematical creative thinking abilities.

Keywords: Contextual problems, Creative thinking skills, Error Identification

1. INTRODUCTION

Creative thinking is essential in the twenty-first century, particularly in the field of education (Cooper, 2021; Konrad et al., 2021; Rahayuningsih et al., 2021). As one of the objectives of mathematics education, creative thinking in mathematics can assist students in understanding what is going on in their surroundings (Puspitasari et al., 2019; Yayuk et al., 2020). Furthermore, creative thinking plays a role in achieving meaningful learning (Ammaralikit & Chattiwat, 2020; Junaedi et al., 2021). As a result, teachers must foster creative thinking in classroom learning activities. Thinking creatively in mathematics is a key component for students in dealing with mathematical difficulties, as it allows students to consider new facts and ideas while solving mathematical problems (Ndiung et al., 2021; Puspitasari et al., 2019). The ability to think creatively in mathematics can also be described as a cognitive function that refers to the ability to develop mathematical ideas and concepts (Nwoke, 2021; Yayuk et al., 2020). Furthermore, the capacity to think creatively in mathematics is one of the features of higher-order thinking to generate new ideas from difficult problems (Ali et al., 2021; Junaedi et al., 2021). As a result, children must be able to think creatively in mathematics.

Many experts have presented indicators of creative thinking skills. A person with strong creative thinking abilities must meet four criteria: fluency, flexibility, originality, and elaboration(Jumadi et al., 2020; Rahayuningsih et al., 2021). Fluency is an ability to develop many types of ideas to solve difficulties. Flexibility refers to capacity to provide multiple solutions to a situation. Originality is capacity to articulate original thoughts that have not previously been considered. Elaboration refers to ability to develop ideas or thoughts and explain problems in detail. Therefore, fluency, Flexibility, Originality, and Elaboration are the indications of creative thinking capacity in this study, according to this explanation.

Solving mathematical problems, particularly contextual ones, is essential for students to develop creative thinking skills (Bintoro et al., 2021; Cho & Kim, 2020; Peltier & Peltier, 2020). This is because contextual problem-solving in mathematics can provide students with various ideas based on real-life experiences (Hawa et al., 2019; Nugroho et al., 2020). In addition, students will be able to solve contextual mathematical problems by correctly applying mathematical procedures or processes (Fonteles Furtado et al., 2019; Hunukumbure et al., 2021). On the other hand, students continue to make errors when dealing with contextual challenges related to creative thinking questions(Haghverdi & Wiest, 2016; Soneira, 2022). As a result, teachers must investigate student errors to incorporate classroom learning strategies properly.

Errors are a significant component of the conceptual knowledge and necessary in mathematics teaching (Barkai, 2021; Hu et al., 2022; Jones et al., 2020). As a result, teachers must be able to identify student errors through effective error analysis (Faizah et al., 2022; Peltier & Peltier, 2020). Therefore, students are encouraged to accomplish the activities assigned by the teacher (Kenney et al., 2020; Santia et al., 2019). Students commonly make interpretive errors, conceptual errors, procedural errors, and computational errors (calculations)(Haghverdi & Wiest, 2016; Kenney et al., 2020; Khalid & Embong, 2019; Peltier & Peltier, 2020). For example, when students turn variables into numbers, they make interpretation errors when translating or concluding a problem statement(Kshetree et al., 2021). This is usually tied to the number object (40). The conceptual error indicates a student's failure to comprehend a concept in the problem at hand and a failure to assess the link in a situation(Ammaralikit & Chattiwat, 2020; Köğce, 2022). Procedural errors occur when students fail to modify an algorithm despite understanding the studied principles (Ammaralikit & Chattiwat, 2020; Lien et al., 2021). Finally, computational error is connected to calculation errors made by students (Al-Jarf, 2022; Emara et al., 2021). These errors were caused by a variety of factors, including students' low disposition toward mathematics, a poor teaching framework, a poor teacher's ability to teach, students' perception of complex mathematics material, students' limited understanding of mathematics, and a lack of understanding in Students' higher order thinking capacity(Kshetree et al., 2021; Prayitno et al., 2022). As a result, assessing students' mental processes when solving mathematical assignments is vital.

The Action-Process-Object-Schema (APOS) hypothesis can be used to investigate students' mental processes when answering contextual challenges on creative thinking questions. The APOS theory is divided into four stages: action, process, object, and schema (Arnawa et al., 2021). In APOS theory, the action is carried out by an individual employing mathematical concepts in conjunction with an exact algorithm and directed by external stimuli during the action phase (Arnawa et al., 2021; Bintoro et al., 2021; Moon, 2019). APOS theory's process phase includes repetitive action and reflection to shift from relying on external signals to relying on internal cues (Arnawa et al., 2021; Boz-Yaman & Yiğit Koyunkaya, 2019; Tatira, 2021). The object phase of APOS theory focuses on recognizing that specific processes and transformations of action are regarded as a single thing to define shifts explicitly (Van Melle & Ferreira, 2022). Finally, the schema phase is a collection of predetermined ideas about actions, processes, objects, and schemas that are combined to build a mathematical structure for solving mathematical problems (Arnawa et al., 2021; Moru, 2020). APOS theory investigates what occurs in a person's mind when learning a mathematical concept and the successes and failures encountered when doing mathematical activities.

APOS theory provides a structured cognitive development pathway that supports mathematics creative thinking skills. For creative thinking to be effective, students often need to develop high-level schemas (the final APOS stage). Incomplete progression through the APOS stages can limit creative thinking to less flexible or shallow approaches, potentially leading to errors. Mathematics creative thinking skills can lead to errors when students generate novel solutions without a complete conceptual understanding. Creative ideas in mathematics need to be based on well-formed schemas; otherwise, students may design flawed approaches due to over-reliance on intuition or incomplete processing. Errors often highlight gaps in APOS development, especially when students fail to transition smoothly between stages (e.g., from process to object). This framework can explain why some errors occur even in students who are adept at generating creative solutions but lack schema understanding.

There have been numerous studies done on error analysis. Research (Didiş Kabar & Erbaş, 2021) shows that students make mistakes in the four presented model problems. According to Polya, research from (Sukoriyanto et al., 2016) reveals that students continue to make errors when tackling permutation and combination problems. According to (Sari et al., 2018), the most common inaccuracy in representational abilities is problem-solving employing arithmetic symbols. According to research from (Khalid & Embong, 2019), errors that arise when completing common problems using integer operations are misconceptions. According to research from (Ozrecberoglu et al., 2022), student accomplishment in answering non-routine math tasks is low since errors occur frequently. Finally, according to the findings of (Jones et al., 2020), students had difficulties solving problems involving fractions.

According to the previous research findings, academics have yet to examine the types of errors caused by students when answering contextual problems on mathematical creative thinking problems utilizing APOS theory. This encouraged the researchers to conduct a study in this area to uncover and identify errors made by elementary school students when solving contextual problems that required creative thinking skills using APOS theory. By using APOS theory, this study seeks to identify students' errors in solving contextual difficulties on creative thinking topics. The researchers chose the APOS theory because it may describe students' mental actions in constructing mathematical concepts. Furthermore, this initial identification is critical for shaping students' creative thinking skills so that relevant learning models based on study findings may be constructed.

2. METHODS

2.1 Research Design

The exploratory descriptive approach is used in this study's qualitative investigation. When students complete a written test on contextual mathematical problems, this approach aims to collect verbal data from their answers. In this study, open-ended questions were used in interviews. This is done to confirm the research subjects' responses. The issues addressed in this study include students' failures in answering contextual mathematical problems on creative thinking skills using the APOS theory (Action-Process-Object-Schema).

2. 2 Research Subject

The participants in this study were all sixth-grade students from one of Cirebon Regency's state elementary schools. Because not all students were chosen as participants, the research subjects were chosen using a purposive sample technique. Fifty students have studied integer material. In the allotted time, students must solve four contextual mathematical problems that can test their creative thinking skills. Based on creative thinking indications, all response papers were collected and examined. Students who performed exceptionally well were not chosen as subjects. On the other hand, students who answered the sheet with errors in solving contextual problems, including numerical material, were considered research subjects. The research subjects were chosen on the teacher's recommendation, specifically students with good communication abilities, so that data on student errors in handling contextual problems on creative thinking skills can be easily examined and found. Two students were chosen for interviews based on the teacher's recommendation.

2.3. Research Instrument

The test and interviews used as research instruments have been construct-validated by two mathematics education experts. The primary purpose of these tests is to identify various errors made by students. The test comprises four contextual questions, specifically designed based on indicators of students' creative thinking abilities. These indicators are based on the four characteristics of creative thinking according to (Kshetree et al., 2021): fluency, flexibility, originality, and elaboration. Interviews are conducted to gather additional information from students' written response sheets. These interviews are unstructured, meaning that the researcher does not prepare specific questions in advance for the research subjects. Instead, students are expected to explain their responses during the interview. Interview questions are based on students' answers on the test sheets. Finally, the researchers confirms that test answers with the interviewed students.

2.4. Data Collection

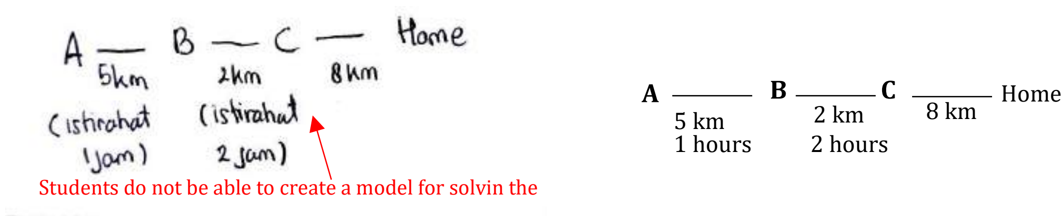
Data were collected from 40 students who completed a test consisting of four essay-style questions addressing contextual challenges related to mathematical creative thinking skills. Each student was given 40 minutes to finish the test and submit their answer sheet. The researchers reviewed the responses, focusing on identifying common errors made by students. The researchers then collaborated with the class teacher to pick six students with strong communication skills for interviews. After selecting research subjects, interviews were conducted to corroborate further responses from the students' written responses. Interviews lasted 45 to 60 minutes, and all of them were recorded. APOS theory was used to conduct interviews for this study to learn more about the errors' students made when tackling challenges involving mathematical creativity in context. The researchers then independently assessed the outcomes of the student interviews. After selecting the research subjects, the researchers conducted interviews to further explore and clarify the students' written responses. Each interview, lasting between 45 and 60 minutes, was fully recorded. Using APOS theory as a framework, the interviews aimed to gain deeper insights into the specific errors students made when approaching contextual challenges in mathematical creativity. The researchers then independently reviewed and analysed the interview results. The next involved data triangulation, achieved by comparing the results of the written test on contextual mathematical problems related to creative thinking skills with the interview insights gathered from researchers and students. Based on these triangulated results, the researchers derived their final findings.

2.5 Data Analysis

Data analysis began with validated transcripts of interviews, student work results, and field notes using triangulation to ensure accuracy. We used an open, inductive thematic approach for coding, mapping transcripts into categories based on the APOS framework. Initial codes were arranged alongside the text to facilitate analysis and were continuously refined to represent participants' voices accurately. Qualitative data coding requires diverse strategies depending on the intended analysis. After reviewing the research questions, further analytical coding was conducted, addressing the research questions through APOS framework themes in a comparative and contracting manner to obtain multi-perspective analytical dimensions. We carefully reviewed the coded transcripts to ensure that statements and quotes were accurately representative within the analysis. All the final coding decisions were guided by the research questions and my understanding of data at hand.

3. RESULTS AND DISCUSSION

According to the Fluency indicator, Figure 1 shows the findings from the contextual problem-solving test of students' critical thinking skills. Figure 1(a) depicts students' responses in Indonesian, and Figure 1(b) depicts students' responses in English. The test results demonstrated that students could not meet the Fluency indicator when answering contextual mathematical problems since they could not provide various solutions. This occurred because students did not comprehend how to solve problems, causing them to make mistakes. It was most likely due to students' inability to comprehend the questions raised in these tasks. As a result, interviews must be conducted to determine students' errors in solving contextual problems related to questions on the Fluency indicator utilizing APOS theory.

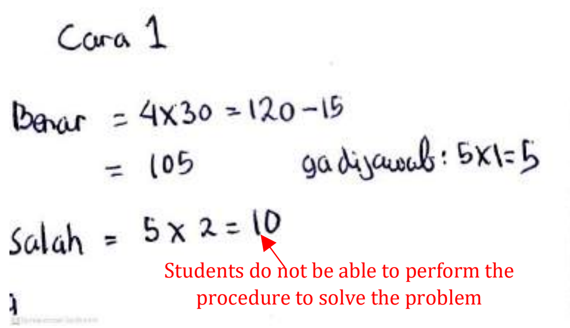


(a) **(b)**

Figure 1 Students's answer on the Fluency indicator (a) Indonesian and (b) English

The results of the interviews revealed that students made an interpretation error. It was shown that students did not write down what they know and what was requested in the response. Furthermore, students drew incorrect route drawings based on the problems in the questions. Students could convert daily language into mathematical language, but they did not understand the meaning of the questions.

Figure 2 shows the results of the contextual problem-solving test of students' creative thinking skills, measured by the Flexibility indicator. Figure 2(a) depicts students' responses in Indonesian, while Figure 2(b) depicts students' responses in English. The test findings demonstrate that students did not meet the Flexibility indicator for solving contextual mathematical problems since they were unable to propose various solutions or approaches to the topic at hand. Furthermore, they cannot present more than one approach or procedure for working on questions. That was most likely due to students' inability to understand the questions raised in answering these issues, causing them to make mistakes. As a result, interviews must be conducted to identify student errors in solving contextual problems using APOS theory.



Rule 1
True = 4x30=120-15 =105
Wrong : 5 x 2 = 10

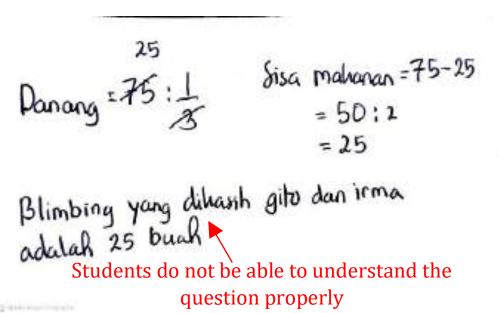
Not Answer = 5 x 1 = 5

(a) **(b)**

Figure 2 Students' answer on the Flexibility indicators (a) Indonesian and (b) English

The interviews revealed that students made an interpretation error. It was shown that students did not write down what they knew and what was requested in the response. They could convert daily language into mathematical language, but they did not understand the significance of the questions. Students made mistakes on the concept too. It was proved by the student applying the operating formula on integers. Furthermore, students make incorrect choices for the numbers that are operated in the problem. Students also made procedural errors because they could not fully explain the answers, and computational errors as well. All of the errors were proven by the answers of the problem.

Figure 3 illustrates the outcomes of the contextual problem-solving test of students' creative thinking skills, as measured by the Originality indicator. Figure 3(a) depicts students' responses in Indonesian, whereas Figure 3(b) depicts students' responses in English. The test findings demonstrate that students were unable to meet the Originality indicator when solving contextual mathematical problems because they were unable to convey fresh concepts that had not previously been considered. This was due to students' incapacity to propose original ideas and their inability to understand the questions in answering these problems. Using APOS theory, interviews were conducted to identify student errors in solving contextual problems related to questions on the Originality indicator.



Danang = 75 : 1/3

Food left = 75 – 25
= 50 : 2
= 25

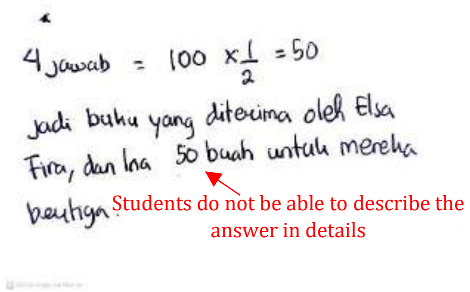
Startfruits given to Gito and Irma are 25.

(a) **(b)**

Figure 3 Students answers on the originality indicator (a) Indonesian and (b) English

The results of the interviews revealed that students erred in their understanding. They did not write down what they knew and did not write down what was requested in the response. Students could convert daily language into mathematical language, but they did not understand the meaning of the questions. Students misunderstood the concept as well. It is proven that students were incorrect in using formulas for fractional operations and integer arithmetic operations. Furthermore, students made incorrect choices for the numbers that were operated in the problem. Students also made procedural errors because they could not fully explain the answers they obtained and made computational errors. Finally, it has been proven that students were incorrect in their final answers.

Figure 4 shows the results of the contextual problem-solving exam of students' creative thinking skills, as measured by the Elaboration indicator. Figure 4(a) depicts students' responses in Indonesian, whereas Figure 4(b) depicts students' responses in English. The exam results demonstrated that students could not meet the Elaboration indicator while answering contextual mathematical problems because they could not develop thoughts or ideas and explain the problems that had been solved in detail. This occurred due to students' failure to describe their answers in detail, causing them to make mistakes. As a result, interviews must be conducted utilizing APOS theory to identify student faults in solving contextual problems related to questions on the Elaboration indicator.



Answer: 100 x ½

= 50

Then, books received by Elsa, Fira, and Lea approximately 50 books for all of them.

(a) **(b)**

Figure 4 Students answers on Elaboration indicator (a) Indonesian and (b) English

The interviews revealed that students made a mistake in their understanding. It was shown that students did not write down what they knew and did not write down what was requested in the response. Students could convert daily language into mathematical language, but they did not understand the significance of the questions. Students made mistakes on the concept too. It was proved by the student applying the operating formula on integers. Furthermore, students make incorrect choices for the numbers that are operated in the problem. Students also made procedural errors because they could not fully explain the answers they obtained, and they made computational errors as well.

Students with low mathematical creative thinking abilities were chosen as research subjects. This is because the students could not answer the four questions presented in contextual situations using the four indications of creative thinking abilities. Students' inability to attain indications of creative thinking skills in contextual mathematical problems was driven by a lack of familiarity with these types of questions (Ilhan & Akin, 2022; Kolar & Hodnik, 2021). In addition, students were only accustomed to challenges that did not necessitate using creative thinking skills. As a result, students must get acquainted with contextual difficulties that necessitate applying creative thinking skills (Rafiee & Abbasian-Naghneh, 2020; Yustina et al., 2022).

To handle contextual difficulties, students' creative thinking skills must be developed. One approach is to employ a learning model that requires students to participate in their learning in class. Material delivery must also focus on results, and problems must provide students with challenges relating to contextual problem. This is consistent with the research(Balakrishnan, 2022), which suggests that one strategy to promote creative thinking skills in elementary school students is to use teaching strategies that require students to be active in classroom learning and acquaint them with addressing complex challenges connected to learning. Furthermore, teachers must provide immediate supportive feedback to students that allows students to actively find their answers so that students do not struggle to solve contextual problems(Kim et al., 2022).

In sixth-grade elementary school, two students with low creative thinking skill make mistakes when answering contextual mathematical problems. Students' common errors in solving contextual problems requiring creative thinking abilities can be divided into four categories: interpretation errors, conceptual errors, procedural errors, and computational/technical errors. Students' interpretation errors occur when they fail to understand the topic or problem in the given context. They are unable to grasp the significance of the questions posed to them. Based on the four questions given, students could not put down what was known and what was asked in the question, causing students to misinterpret the meaning. Furthermore, in question one, the student incorrectly described the sketch of the route image based on the difficulty of the problem. Students created a route using only straight lines, although the question stated that the path should return to the starting position because Budi returns to the origin. Students were also incorrect in their findings in response to the inquiry. Students made errors in responding correctly to the presented contextual difficulties based on the four questions. Students also did not fully comprehend the questions presented. This was due to students' inability to define or comprehend sketch drawings in a specific topic (Özdemir & Dede, 2022).

Students committed conceptual errors, such as incorrectly applying the formula for arithmetic operations with mixed integers. In question number two, students did arithmetic operations on integers without considering which rule was stronger between addition, subtraction, multiplication, and division operations causing them to perform incorrectly. Students also misunderstood the division process of numbers in question number two. In response to question number two, the students answered $75 \div \frac{1}{3}$. P In this question, the students crossed out the numbers 75 and 3. It was shown that the students had a wrong idea of division and multiplication operations. The correct notion was $75 \div \frac{1}{3} = 75 \times 3$. Additionally, students choose the incorrect number to operate on in the problem. This was because students did not comprehend what was being requested in the problem, causing numbers that did not need to be operated to become operational (Joung & Kim, 2022).

Based on the four questions, students experienced errors in choosing the numbers to operate in the questions. This is due to students’ failure to read the questions carefully, resulting in students misunderstanding what the questions signify. This demonstrates that students' knowledge of mathematical concepts remains low. This is reinforced by (Karakuş et al., 2022), which indicates that their conceptual comprehension is poor when students answer specific mathematical problems. As a result, students make conceptual errors. The finding is supported by study (Tooher & Johnson, 2020), which found that students struggle to grasp particular mathematical topics if they do not understand the ideas relevant to the studied issues. Students will make mistakes when answering problems, particularly contextual ones. Conceptual errors can also develop as a result of prior knowledge. This is consistent with the findings of a study (Jarrah et al., 2022), which found that students' conceptual errors are also caused by prior mathematical learning. For example, students are unable to comprehend integer concepts since merely memorize integer formulas without applying the concept and how to apply them. As a result, students struggle to gain a correct and comprehensive comprehension of a concept (Barbieri & Booth, 2020).

Students made procedural errors, including failing to explain the steps on the answer sheet adequately. Students only mentioned the outcome in question number one. Students were unable to explain the methods taken to acquire the answer from number one. Then, on problems 2 and 3, students could explain the phases of the response, but only partially because the final answers were incorrect. The students could not clarify their answers to question four because they misinterpreted the significance of the questions. Furthermore, students were incorrect in concluding the results of the given problem. This was demonstrated by question five, in which students assumed that the books delivered to Elsa, Fira, and Ina were the same as 50 books. The problem fails to indicate that Elsa, Fira, and Ina's book distribution was the same amount. As a result, students did not understand the significance of the problem, and their conclusions were incorrect. Students were also incorrect in executing integer operations when solving problems, even though they had reached the proper conclusions. Therefore, students need to apply all the principles required to answer the problem to avoid making errors in determining the outcome (Hu et al., 2022). Students must be able to present valid mathematical reasons, draw conclusions, and develop generalizations in order to solve a specific mathematical problem(Köğce, 2022).

Students' technical or computational errors happened during the calculation procedure. For example, it could be discovered in the procedure of multiplying integers in problem number two. The student carries out the operation $6 \times (-1) = -5$. The conclusions of these calculations were incorrect; hence students' final answers to the problems were incorrect. This was consistent with the study's findings(Khalid & Embong, 2019), which found that most students had broad misconceptions regarding integer operations, such as the multiplication of positive and negative integers. Errors in dividing integers by fractions occured because students were less attentive while performing operations. As a result, a technical error happened. For example, in question three, students completed the operation $75 \div \frac{1}{3} = 25$. The outcomes of these calculations were inaccurate, causing students to conclude the final answer to the presented questions incorrectly. According to the study, the most common mistakes students make in the operation of dividing integers are those who are negligent in using the methods of the problems supplied (Üzel, 2018). As a result, students must have strong fundamental mathematical problem-solving abilities to solve contextual mathematical problems (Sternberg et al., 2021). This is essential to ensure that students' mistakes do not reoccur.

According to the findings, sixth-grade students were still in the action stage of the APOS theory. This occurs because students lack an APOS conceptual structure, causing them to make errors when faced with contextual mathematical problems. For example, students have trouble implementing integer operations due to a lack of conceptual structure connected to the process, object, and schema stages(Kshetree et al., 2021). This demonstrates that students cannot manage the application of theorems and formulas required for specific mathematical problems. Based on the APOS theory analysis findings, students have difficulties understanding the idea of operations on numbers. This is because when the students were at the previous level, they could not understand the notion of operations on integers, causing them to make errors in solving the problems presented. Students only memorize formulas, so they struggle when they learn about the idea of operations on integers. In addition, students lack experience understanding integer operations, do not fully understand the concept of integer operations, and have minimal prior knowledge of integer operations at the previous level. As a result, teachers must have an effective strategy to identify student errors. One technique for reducing student errors in handling contextual problems is to hold open discussions focusing on efforts to overcome student errors during the learning process (Ilhan & Akin, 2022).

Assessing and analyzing students' errors in completing contextual problems on creative thinking skills is considered an essential tool for learning(Rahayuningsih et al., 2021). Furthermore, it is indicated that to overcome cognitive obstacles in solving difficulties presented in learning mathematics, and students must have a positive mindset and optimal thinking activities that activate prior knowledge and experience in solving specific problems. Since students in different courses differ in their capacities for creative thought, the understanding of particular students should be considered while designing a teacher's thinking activity(Jumadi et al., 2020).

These findings suggest that teachers should appropriately prepare students on the classroom's procedural and conceptual parts of mathematics. Both features are critical in comprehending mathematical material (Barbieri & Booth, 2020). Identifying students' errors in addressing contextual mathematical problem and the skill to think creatively on integer operations has helped teachers recognize students' shortcomings. This will assist the teacher in preparing classroom activities and addressing errors that occur. Students' errors are caused by a lack of creative thinking skills when tackling contextual mathematical problems. According to (Tooher & Johnson, 2020), a student with low notions in creative thinking skills will make mistakes in solving the problem. Therefore, students' skill to think creatively must be developed so that similar errors will not occur again. After improving their creative thinking skills, students will develop their own formulas or principles for solving mathematical problems. According to the research, strengthening mathematical creative thinking skills would allow students to pay attention to all components required to assist in solving mathematical problems, allowing them to find formulas or rules on their own (Foster, 2021).

4. CONCLUSSION

Based on the research results and discussion, it concludes that the students selected for the study did not meet the four creative thinking markers of fluency, flexibility, originality, and elaboration. This incapacity was caused by errors made by students when tackling contextual problem-solving difficulties using creative thinking skills. According to the APOS theory, student errors include (1) Misinterpretation errors: incorrectly converting the questions into mathematical language/symbols and misinterpreting the given questions; (2) Conceptual errors: students misused formulas while counting fractions and integers. Furthermore, students made wrong choices for the numbers that were operated in the problem; (3) Procedural error: the student improperly concluded the question. This was because students failed to pay attention to what was asked in the question and were incorrect in carrying out the processes to solve the problem because students were unable to explain the solutions received. (4) Technical/computing errors: students made errors in computations involving integer operations, and students' final answers to the questions they worked on were incorrect.

Future study should lead to the development of new learning models capable of improving mathematical creative thinking skills. This is significant because research shows that kids with strong creative thinking skills adapt fast to new issues. On the other hand, students who lack creative thinking skills will have difficulty solving an issue. Future research should investigate how students think while tackling contextual problems in mathematics. Identifying students' cognitive processes will help them better grasp because they take a particular approach to problem-solving. When teachers understand their students' thought processes, they can identify students' challenges quickly when solving mathematical problems. As a result, the teacher can modify the learning paradigm for the next meeting.

REFERENCES

Al-Jarf, R. (2022). Student-Interpreters' Foreign Proper Noun Pronunciation Errors in English-Arabic and Arabic-English Media Discourse Interpreting. *International Journal of Translation and Interpretation Studies*, *2*(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature Review : Mathematical Creative Thinking Ability , and Students ' Self Regulated Learning to Use an Open Ended Approach. *Malikussaleh Journal of Mathematics Learning*, *4*(1), 52–61.

Ammaralikit, A., & Chattiwat, W. (2020). Effects of Business Reading Model on Thai Learners' Reading and Creative Thinking Abilities. *English Language Teaching*, *13*(5), 191. https://doi.org/10.5539/elt.v13n5p191

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? *International Journal of Instruction*, *14*(3), 175–186. https://doi.org/10.29333/iji.2021.14310a

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: a study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education*, *32*(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on display: Incorrect examples refine equation solving and algebraic feature knowledge. *Applied Cognitive Psychology*, *34*(4), 862–878. https://doi.org/10.1002/acp.3663

Barkai, R. (2021). Using cases as a means to discuss errors in mathematics teacher education. *Education Sciences*, *11*(10). https://doi.org/10.3390/educsci11100575

Bintoro, H. S., Walid, & Mulyono. (2021). The Spatial Thinking Process of the Field-Independent Students based on Action-Process-Object-Schema Theor. *European Journal of Educational Research*, *10*(4), 1807–1823.

Boz-Yaman, B., & Yiğit Koyunkaya, M. (2019). Examination of Pre-service Mathematics Teachers' Mental Constructions of Function Transformation. *Acta Didactica Napocensia*, *12*(1), 33–56. https://doi.org/10.24193/adn.12.1.3

Cho, M. K., & Kim, M. K. (2020). Investigating elementary students' problem solving and teacher scaffolding in solving an Ill-structured problem. *International Journal of Education in Mathematics, Science and Technology*, *8*(4), 274–289. https://doi.org/10.46328/IJEMST.V8I4.1148

Cooper, A. A. (2021). Incorporating Critical and Creative Thinking in a Transitions Course. *Primus*, *31*(9), 995–1006. https://doi.org/10.1080/10511970.2020.1805659

Didiş Kabar, M. G., & Erbaş, A. K. (2021). Pre-service secondary mathematics teachers' anticipation and identification of students' thinking in the context of modelling problems. *International Journal of Mathematical Education in Science and Technology*, *52*(2), 208–236. https://doi.org/10.1080/0020739X.2019.1670368

Emara, M., Hutchins, N. M., Grover, S., Snyder, C., & Biswas, G. (2021). Examining student regulation of collaborative, computational, problem-solving processes in openended learning environments. *Journal of Learning Analytics*, *8*(1), 49–74. https://doi.org/10.18608/JLA.2021.7230

Faizah, S., Nusantara, T., Sudirman, & Rahardi, R. (2022). Constructing Students' Thinking Process through Assimilation and Accommodation Framework. *Mathematics Teaching-Research Journal*, *14*(1), 253–269.

Fonteles Furtado, P. G., Hirashima, T., Hayashi, Y., & Maeda, K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. *Research and Practice in Technology Enhanced Learning*, *14*(1), 1–18. https://doi.org/10.1186/s41039-019-0096-1

Foster, M. K. (2021). Design Thinking: A Creative Approach to Problem Solving. *Management Teaching Review*, *6*(2), 123–140. https://doi.org/10.1177/2379298119871468

Haghverdi, M., & Wiest, L. R. (2016). The Effect of Contextual and Conceptual Rewording on Mathematical Problem- Solving Performance. *The Mathematics Educator*, *25*(1), 56–73.

Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient approach to teach literary sociology. *International Journal of Instruction*, *12*(1), 283–298. https://doi.org/10.29333/iji.2019.12119a

Hu, Q., Son, J. W., & Hodge, L. (2022). Algebra Teachers' Interpretation and Responses to Student Errors in Solving Quadratic Equations. *International Journal of Science and Mathematics Education*, *20*(3), 637–657. https://doi.org/10.1007/s10763-021-10166-1

Hunukumbure, A. D., Horner, P. J., Fox, J., & Thakerar, V. (2021). An online discussion between students and teachers: a way forward for meaningful teacher feedback? *BMC Medical Education*, *21*(1), 1–9.

https://doi.org/10.1186/s12909-021-02730-8

Ilhan, A., & Akin, M. F. (2022). Analysis of Contextual Problem Solutions, Mathematical Sentences, and Misconceptions of Pre-Service Mathematics Teachers. *International Electronic Journal of Mathematics Education*, *17*(1), em0666. https://doi.org/10.29333/iejme/11470

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(6). https://doi.org/10.29333/ejmste/12070

Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. *School Science and Mathematics*, *120*(4), 232–243. https://doi.org/10.1111/ssm.12402

Joung, E., & Kim, Y. R. (2022). Identifying Preservice Teachers' Concept-based and Procedure-based Error patterns in Multiplying and Dividing Decimals. *International Journal of Education in Mathematics, Science and Technology*, *10*(3), 549–567. https://doi.org/10.46328/ijemst.2227

Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE)*, *9*(2), 415–420. https://doi.org/10.11591/ijere.v9i2.20531

Junaedi, Y., Wahyudin, & Juandi, D. (2021). Mathematical creative thinking ability of junior high school students' on polyhedron. *Journal of Physics: Conference Series*, *1806*(1), 36–45. https://doi.org/10.1088/1742-6596/1806/1/012069

Karakuş, D., Özkaya, M., & Konyaliglu, A. C. (2022). Geogebra in the Correction and Understanding of Errors Regarding the Concept of Asymptote. *Shanlax International Journal of Education*, *10*(2), 67–79. https://doi.org/10.34293/education.v10i2.4400

Kenney, R., An, T., Kim, S. H., Uhan, N. A., Yi, J. S., & Shamsul, A. (2020). Linear Programming Models: Identifying Common Errors in Engineering Students' Work with Complex Word Problems. *International Journal of Science and Mathematics Education*, *18*(4), 635–655. https://doi.org/10.1007/s10763-019-09980-5

Khalid, M., & Embong, Z. (2019). Sources and Possible Causes of Errors and Misconceptions in Operations of Integers. *International Electronic Journal of Mathematics Education*, *15*(2). https://doi.org/10.29333/iejme/6265

Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of Scaffolding on Information Literacy and Argumentation Skills in Virtual Field Trips and Problem-Based Learning for Scientific Problem Solving. *International Journal of Science and Mathematics Education*, *20*(2), 215–236. https://doi.org/10.1007/s10763-020-10145-y

Köğce, D. (2022). Examination of Mathematical Errors and Mistakes in Calculus Course. *Educational Policy Analysis and Strategic Research*, *17*(1), 295–311. https://doi.org/10.29329/epasr.2022.248.15

Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. *European Journal of Educational Research*, *10*(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467

Konrad, M., Editor, A., & Smith, J. E. (2021). *Creative Self-Efficacy : An Essential Transition Skill for Students With Learning Disabilities*. https://doi.org/10.1177/10534512211024938

Kshetree, M. P., Acharya, B. R., Khanal, B., & Panthi, R. K. (2021). Eighth Grade Students' Misconceptions and Errors in Mathematics Learning in Nepal. *European Journal of Educational Research*, *10*(4), 1907–1918.

Lien, N. T. N., Khuyen, N. T. T., Tho, N. T., Hoa, N. N., Hanh, N. T., Tho, C. C., Hai, T. D., & Van Bien, N. (2021). Teachers' feelings of safeness in school-family-community partnerships: Motivations for sustainable development in moral education. *International Journal of Evaluation and Research in Education*, *10*(1), 97–107. https://doi.org/10.11591/ijere.v10i1.20798

Moon, K. (2019). PRESERVICE TEACHERS? UNDERSTANDING OF TWO-VARIABLE INEQUALITIES: APOS THEORY. *Proceedings of the 41st Annual Meeting of PME-NA*, 686–694.

Moru, E. K. (2020). An APOS Analysis of University Students' Understanding of Derivatives: A Lesotho Case Study. *African Journal of Research in Mathematics, Science and Technology Education*, *0*(0), 1–14. https://doi.org/10.1080/18117295.2020.1821500

Ndiung, S., Sariyasa, Jehadus, E., & Apsar, R. A. (2021). The Effect of Treffinger Creative Learning Model with the Use RME Principles on Creative Thinking Skill and Mathematics Learning Outcome. *International Journal of Instruction*, *14*(2), 873–888.

Nugroho, A. A., Nizarudin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students ' creative thinking in the use of representations in solving mathematical problems based on cognitive style. *Journal of Research and Advances in Mathematics Education*, *5*(2), 202–217.

https://doi.org/10.23917/jramathedu.v5i2.9983

Nwoke, B. L. (2021). Enhancing primary school pupils ' mathematics creative ability through activity based learning approach. *Malikussaleh Journal of Mathematics Learning (MJML)*, *4*(2), 70–76.

Özdemir, E., & Dede, E. (2022). INVESTIGATION OF THE WAYS PROSPECTIVE MATHEMATICS TEACHERS RESPOND TO STUDENTS ' ERRORS : AN EXAMPLE OF OF THE EQUAL SIGN. *International Online Journal of Education and Teaching (IOJET)*, *9*(2), 723–739.

Ozrecberoglu, N., Aydın, S., & Aydın, O. (2022). Students' Skills In Solving Non-Routine Mathematical Problems. *Education Quarterly Reviews*, *5*(2), 446–461. https://doi.org/10.31014/aior.1993.05.02.504

Peltier, C., & Peltier, T. K. (2020). Mining Instruction From Student Mistakes: Conducting an Error Analysis for Mathematical Problem Solving. *Beyond Behavior*, *29*(3), 141–151. https://doi.org/10.1177/1074295620903050

Prayitno, A. T., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2022). Identification of graph thinking in solving mathematical problems naturally. *Participatory Educational Research*, *9*(2), 118–135. https://doi.org/10.17275/per.22.32.9.2

Puspitasari, L., In, A., & Syaifuddin, M. (2019). Analysis of Students ' Creative Thinking in Solving Arithmetic Problems. *INTERNATIONAL ELECTRONIC JOURNAL OF MATHEMATICS EDUCATION*, *14*(1), 49–60.

Rafiee, M., & Abbasian-Naghneh, S. (2020). Willingness to Write (WTW): Development of a model in EFL writing classrooms. *Cogent Education*, *7*(1), 0–16. https://doi.org/10.1080/2331186X.2020.1847710

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. *Participatory Educational Research*, *8*(3), 285–299. https://doi.org/10.17275/per.21.66.8.3

Santia, I., Purwanto, Sutawidjadja, A., Sudirman, & Subanji. (2019). Exploring mathematical representations in solving ill-structured problems: The case of quadratic function. *Journal on Mathematics Education*, *10*(3), 365–378. https://doi.org/10.22342/jme.10.3.7600.365-378

Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with react strategy in solving the problems of mathematical representation ability. *Journal on Mathematics Education*, *9*(1), 121–128. https://doi.org/10.22342/jme.9.1.4378.121-128

Soneira, C. (2022). The Use of Representations when Solving Algebra Word Problems and the Sources of Solution Errors. *International Journal of Science and Mathematics Education*, *20*(5), 1037–1056. https://doi.org/10.1007/s10763-021-10181-2

Sternberg, R. J., Glaveanu, V., Karami, S., Kaufman, J. C., Phillipson, S. N., & Preiss, D. D. (2021). Meta-intelligence: understanding, control, and interactivity between creative, analytical, practical, and wisdom-based approaches in problem solving. *Journal of Intelligence*, *9*(2). https://doi.org/10.3390/jintelligence9020019

Sukoriyanto, S., Nusantara, T., Subanji, S., & Chandra, T. D. (2016). Students' Errors in Solving the Permutation and Combination Problems Based on Problem Solving Steps of Polya. *International Education Studies*, *9*(2), 11. https://doi.org/10.5539/ies.v9n2p11

Tatira, B. (2021). Mathematics Education Students' Understanding of Binomial Series Expansion Based on the APOS Theory. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(12), 1–13. https://doi.org/10.29333/EJMSTE/11287

Tooher, H., & Johnson, P. (2020). The role of analogies and anchors in addressing students' misconceptions with algebraic equations. *Issues in Educational Research*, *30*(2), 756–781.

Üzel, D. (2018). Investigation of misconceptions and errors about division operation in fractions. *Universal Journal of Educational Research*, *6*(11), 2656–2662. https://doi.org/10.13189/ujer.2018.061131

Van Melle, J., & Ferreira, M. (2022). Developing Students' Intercultural Sensitivity at the Home Campus: An Innovative Approach Using the Theory of the Creative Action Methodology Pedagogy. *Teaching and Learning Inquiry*, *10*, 1–23. https://doi.org/10.20343/TEACHLEARNINQU.10.12

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yustina, Mahadi, I., Ariska, D., Arnentis, & Darmadi. (2022). The Effect of E-Learning Based on the Problem-Based Learning Model on Students' Creative Thinking Skills During the Covid-19 Pandemic. *International Journal of Instruction*, *15*(2), 329–348. https://doi.org/10.29333/iji.2022.15219a

Bukti konfirmasi review dan hasil review kedua revision required

24 November 2024

Khoerul Umam <khoerul.umam@uhamka.ac.id>

[HASSS] Editor Decision - Accept Submission

5 messages

Korakoch Attaviriyanupap via Thai Journals Online (ThaiJO) <admin@tci-thaijo.org> Sun, Nov 24, 2024 at 2:17 PM
Reply-To: Korakoch Attaviriyanupap <hasss.editor@su.ac.th>
To: Khoerul Umam <khoerul.umam@uhamka.ac.id>, Ardi Dwi Susandi <ardi.official@ecampus.ut.ac.id>, Muhammad Irfan <irvahn@gmail.com>, Mohd Isha Bin Awang <isha@uum.my.edu>, Eka Nana Susanti <eka_nana@uhamka.ac.id>, Supandi <supandi@uhamka.ac.id>

Dear Khoerul Umam, Ardi Dwi Susandi, Muhammad Irfan, Mohd Isha Bin Awang, Eka Nana Susanti, Supandi,

We have reached a decision regarding your submission to Humanities, Arts and Social Sciences Studies, "MATHEMATICAL CREATIVE THINKING SKILL: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS ".

Our decision is to: Accept Submission.

However, before issuing the official acceptance letter and really proceeding with the copyediting process, please proofread and edit all the in-text citations and the references to follow the **APA 7th style** and have the manuscript proofread by **a qualified native speaker of English** or a professional language editing service. The following files are needed for resubmission:

1) the proofread manuscript with track changes*

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In order to expedite publication of the manuscript, we would appreciate receiving the revised manuscript **as soon as possible**.

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Kind regards,
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Khoerul Umam <khoerul.umam@uhamka.ac.id> Tue, Nov 26, 2024 at 4:59 AM
To: Korakoch Attaviriyanupap <hasss.editor@su.ac.th>
Cc: Ardi Dwi Susandi <ardi.official@ecampus.ut.ac.id>, Muhammad Irfan <irvahn@gmail.com>, Mohd Isha Bin Awang <isha@uum.my.edu>, Eka Nana Susanti <eka_nana@uhamka.ac.id>, Supandi <supandi@uhamka.ac.id>

Dear Editor

Thank you for your acceptance status. Now, we are working with our english native partner to meet your requirements as soon as possible.

Thank you very much for your wonderful cooperation.

Warm Regards

Khoerul Umam
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Action: failed
Status: 5.1.2
Diagnostic-Code: smtp; DNS Error: DNS type 'mx' lookup of uum.my.edu responded with code NXDOMAIN
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Khoerul Umam <khoerul.umam@uhamka.ac.id> Tue, Dec 10, 2024 at 11:22 AM
To: Korakoch Attaviriyanupap <hasss.editor@su.ac.th>
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Dear Editor

We would like to inform you that we have met your requests upon the following documents:

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3) the file of a language proofreading certificate which includes the title of the manuscript and the authors' name.

We are very glad that we have been striving to meet your requirements upon our accepted paper. All documents have been attached in this message which also include turnitin check. Furthermore, we have a request to change the email address of one of authors (Muhammad Irfan) from irvahn@gmail.com to muhammadirfan@uny.ac.id. Hopefully, our documents have met your requests.

Warm Regard,

Khoerul Umam

Universitas Muhammadiyah Prof DR HAMKA.

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MATHEMATICAL CREATIVE THINKING ~~SKILL~~SKILLS: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS

ABSTRACT

Individuals with strong creative thinking abilities are particularly adept at effectively addressing mathematical contextual problems. However, ~~it is common for~~ students ~~to~~often need more vital creative thinking skills ~~within~~in the classroom ~~setting, often~~, frequently due to ~~various~~ errors ~~made by students~~they make themselves. This study aims to identify students' specific errors when ~~attempting to solve~~solving contextual problems related to integer operations. ~~Utilizing~~This research adopts a qualitative approach, ~~this research employs~~using an exploratory~~,~~ and descriptive technique ~~and focuses~~, focusing on sixth-grade elementary school students. Participants were selected based on the teacher's recommendations, specifically targeting students with strong ~~communications~~communication skills to comprehensively examine their errors in dealing with contextual problems and their creative thinking skills. The research utilized tests and interviews as instruments for data collection, incorporating methodologies such as testing, interviewing, and triangulation. The results indicate a significant deficiency in students' innovative thinking skills, rendering them unable to solve problems effectively, which leads to an inability to meet the four criteria of creative thinking. Based on the Action-Process-Objects-Scheme (APOS) theory, the identified errors in students' approaches to contextual mathematical problems can be ~~categorize~~categorized into four types: (1) interpretive errors, (2) errors in conceptual understanding, (3) procedural errors, and (4) computational or technical errors. The insight gained from this study can inform the design of integer learning activities, helping minimize contextual problem-solving mistakes that require creative thinking skills. Consequently, further research is essential to develop a mathematical learning model that can enhance students' mathematical creative thinking abilities.

Keywords: Contextual problems, Creative thinking skills, Error Identification

1. INTRODUCTION

~~Creative thinking is essential in the twenty-first century, particularly in the field of education (Cooper, 2021; Konrad et al., 2021; Rahayuningsih et al., 2021). As one of the objectives of mathematics education, creative thinking in mathematics can assist students in understanding what is going on in their surroundings (Puspitasari et al., 2019; Yayuk et al., 2020). Furthermore, creative thinking plays a role in achieving meaningful learning (Ammaralikit & Chattiwat, 2020; Junaedi et al., 2021). As a result, teachers must foster creative thinking in classroom learning activities. Thinking creatively in mathematics is a key component for students in dealing with mathematical difficulties, as it allows students to consider new facts and ideas while solving mathematical problems (Ndiung et al., 2021; Puspitasari et al., 2019). The ability to think creatively in mathematics can also be described as a cognitive function that refers to the ability to develop mathematical ideas and concepts (Nwoke, 2021; Yayuk et al., 2020). Furthermore, the capacity to think creatively in mathematics is one of the features of higher-order thinking to generate new ideas from difficult problems (Ali et al., 2021; Junaedi et al., 2021). As a result, children must be able to think creatively in mathematics.~~

~~Many experts have presented indicators of creative thinking skills. A person with strong creative thinking abilities must meet four criteria: fluency, flexibility, originality, and elaboration(Jumadi et al., 2020; Rahayuningsih et al., 2021). Fluency is an ability to develop many types of ideas to solve difficulties. Flexibility refers to capacity to provide multiple solutions to a situation. Originality is capacity to articulate original thoughts that have not previously been considered. Elaboration refers to ability to develop ideas or thoughts and explain problems in detail. Therefore, fluency, Flexibility, Originality, and Elaboration are the indications of creative thinking capacity in this study, according to this explanation.~~

~~Solving mathematical problems, particularly contextual ones, is essential for students to develop creative thinking skills (Bintoro et al., 2021; Cho & Kim, 2020; Peltier & Peltier, 2020). This is because contextual problem-solving in mathematics can provide students with various ideas based on real-life experiences (Hawa et al., 2019; Nugroho et al., 2020). In addition, students will be able to solve contextual mathematical problems by correctly applying mathematical procedures or processes (Fonteles Furtado et al.,~~

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2019; Hunukumbure et al., 2021). On the other hand, students continue to make errors when dealing with contextual challenges related to creative thinking questions(Haghverdi & Wiest, 2016; Soneira, 2022). As a result, teachers must investigate student errors to incorporate classroom learning strategies properly.

Errors are a significant component of the conceptual knowledge and necessary in mathematics teaching (Barkai, 2021; Hu et al., 2022; Jones et al., 2020). As a result, teachers must be able to identify student errors through effective error analysis (Faizah et al., 2022; Peltier & Peltier, 2020). Therefore, students are encouraged to accomplish the activities assigned by the teacher (Kenney et al., 2020; Santia et al., 2019). Students commonly make interpretive errors, conceptual errors, procedural errors, and computational errors (calculations)(Haghverdi & Wiest, 2016; Kenney et al., 2020; Khalid & Embong, 2019; Peltier & Peltier, 2020). For example, when students turn variables into numbers, they make interpretation errors when translating or concluding a problem statement(Kshetree et al., 2021). This is usually tied to the number object (40). The conceptual error indicates a student's failure to comprehend a concept in the problem at hand and a failure to assess the link in a situation(Ammaralikit & Chattiwat, 2020; Köğce, 2022). Procedural errors occur when students fail to modify an algorithm despite understanding the studied principles (Ammaralikit & Chattiwat, 2020; Lien et al., 2021). Finally, computational error is connected to calculation errors made by students (Al-Jarf, 2022; Emara et al., 2021). These errors were caused by a variety of factors, including students' low disposition toward mathematics, a poor teaching framework, a poor teacher's ability to teach, students' perception of complex mathematics material, students' limited understanding of mathematics, and a lack of understanding in Students' higher order thinking capacity(Kshetree et al., 2021; Prayitno et al., 2022). As a result, assessing students' mental processes when solving mathematical assignments is vital.

The Action-Process-Object-Schema (APOS) hypothesis can be used to investigate students' mental processes when answering contextual challenges on creative thinking questions. The APOS theory is divided into four stages: action, process, object, and schema (Arnawa et al., 2021). In APOS theory, the action is carried out by an individual employing mathematical concepts in conjunction with an exact algorithm and directed by external stimuli during the action phase (Arnawa et al., 2021; Bintoro et al., 2021; Moon, 2019). APOS theory's process phase includes repetitive action and reflection to shift from relying on external signals to relying on internal cues (Arnawa et al., 2021; Boz-Yaman & Yiğit Koyunkaya, 2019; Tatira, 2021). The object phase of APOS theory focuses on recognizing that specific processes and transformations of action are regarded as a single thing to define shifts explicitly (Van Melle & Ferreira, 2022). Finally, the schema phase is a collection of predetermined ideas about actions, processes, objects, and schemas that are combined to build a mathematical structure for solving mathematical problems (Arnawa et al., 2021; Moru, 2020). APOS theory investigates what occurs in a person's mind when learning a mathematical concept and the successes and failures encountered when doing mathematical activities.

Creative thinking is essential in the twenty-first century, particularly in the field of education (Cooper, 2021; Konrad et al., 2021; Rahayuningsih et al., 2021). As one of the objectives of mathematics education, creative thinking in mathematics can assist students in understanding their surroundings (Puspitasari et al., 2019; Yayuk et al., 2020). Furthermore, creative thinking plays a role in achieving meaningful learning (Ammaralikit & Chattiwat, 2020; Junaedi et al., 2021). As a result, teachers must foster creative thinking in classroom learning activities. Thinking creatively in mathematics is a key component for students in addressing mathematical difficulties, as it allows them to consider new facts and ideas while solving mathematical problems (Ndiung et al., 2021; Puspitasari et al., 2019). The ability to think creatively in mathematics can also be described as a cognitive function that refers to the capacity to develop mathematical ideas and concepts (Nwoke, 2021; Yayuk et al., 2020). Furthermore, the ability to think creatively in mathematics is one of the features of higher-order thinking, allowing students to generate new ideas from difficult problems (Ali et al., 2021; Junaedi et al., 2021). As a result, students must be able to think creatively in mathematics.

Many experts have presented indicators of creative thinking skills. A person with strong creative thinking abilities must meet four criteria: fluency, flexibility, originality, and elaboration (Jumadi et al., 2020; Rahayuningsih et al., 2021). Fluency is the ability to generate many types of ideas to solve problems. Flexibility refers to the capacity to provide multiple solutions to a situation. Originality is the ability to articulate original thoughts that have not previously been considered. Elaboration refers to the ability to develop ideas or thoughts and explain problems in detail. Therefore, fluency, flexibility, originality, and elaboration are the indicators of creative thinking ability in this study, according to this explanation.

Solving mathematical problems, particularly contextual ones, is essential for students to develop creative thinking skills (Bintoro et al., 2021; Cho & Kim, 2020; Peltier & Peltier, 2020). This is because contextual problem-solving in mathematics can provide students with various ideas based on real-life experiences (Hawa et al., 2019; Nugroho et al., 2020). In addition, students will be able to solve contextual mathematical problems by correctly applying mathematical procedures or processes (Fonteles Furtado et al., 2019; Hunukumbure et al., 2021). On the other hand, students continue to make errors when dealing with contextual challenges related to creative thinking questions (Haghverdi & Wiest, 2016; Soneira, 2022). As a result, teachers must investigate student errors in order to incorporate appropriate classroom learning strategies.

Errors are a significant component of conceptual knowledge and are necessary in mathematics teaching (Barkai, 2021; Hu et al., 2022; Jones et al., 2020). As a result, teachers must be able to identify student errors through effective error analysis (Faizah et al., 2022; Peltier & Peltier, 2020). Therefore, students are encouraged to complete the activities assigned by the teacher (Kenney et al., 2020; Santia et al., 2019). Students commonly make interpretive errors, conceptual errors, procedural errors, and computational errors (calculations) (Haghverdi & Wiest, 2016; Kenney et al., 2020; Khalid & Embong, 2019; Peltier & Peltier, 2020). For example, when students turn variables into numbers, they make interpretation errors when translating or concluding a problem statement (Kshetree et al., 2021). This is usually tied to the number object (40). The conceptual error indicates a student's failure to comprehend a concept in the problem at hand and a failure to assess the connection in a situation (Ammaralikit & Chattiwat, 2020; Köğce, 2022). Procedural errors occur when students fail to modify an algorithm despite understanding the studied principles (Ammaralikit & Chattiwat, 2020; Lien et al., 2021). Finally, computational errors are connected to calculation mistakes made by students (Al-Jarf, 2022; Emara et al., 2021). These errors were caused by a variety of factors, including students' low disposition toward mathematics, a poor teaching framework, insufficient teaching ability, students' perception of complex mathematics material, students' limited understanding of mathematics, and a lack of understanding in students' higher-order thinking capacity (Kshetree et al., 2021; Prayitno et al., 2022). As a result, assessing students' mental processes when solving mathematical assignments is vital.

The Action-Process-Object-Schema (APOS) theory can be used to investigate students' mental processes when answering contextual challenges related to creative thinking questions. The APOS theory is divided into four stages: action, process, object, and schema (Arnawa et al., 2021). In APOS theory, the action phase is carried out by an individual employing mathematical concepts in conjunction with a specific algorithm, directed by external stimuli during the action phase (Arnawa et al., 2021; Bintoro et al., 2021; Moon, 2019). The process phase of APOS theory includes repetitive actions and reflection, which help shift from relying on external signals to relying on internal cues (Arnawa et al., 2021; Boz-Yaman & Yiğit Koyunkaya, 2019; Tatira, 2021). The object phase of APOS theory focuses on recognizing that specific processes and transformations of action are regarded as a single entity, allowing for explicit shifts (Van Melle & Ferreira, 2022). Finally, the schema phase is a collection of predetermined ideas about actions, processes, objects, and schemas that are combined to build a mathematical structure for solving mathematical problems (Arnawa et al., 2021; Moru, 2020). APOS theory investigates what occurs in a person's mind when learning a mathematical concept and the successes and failures encountered during mathematical activities.

APOS theory provides a structured cognitive development pathway that supports ~~mathematics~~ creative thinking skills in mathematics. For creative thinking to be effective, students often need to develop high-level schemas (the final APOS stage). Incomplete progression through the APOS stages can limit creative thinking to less flexible or shallow approaches, potentially leading to errors. ~~Mathematics creative~~Creative thinking ~~skills~~in mathematics can lead to errors when students generate novel solutions without a complete conceptual understanding. Creative ideas in mathematics need to be based on well-formed schemas; otherwise, students may design flawed approaches due to over-reliance on intuition or incomplete processing. Errors

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Formatted: Font color: Auto, English (United Kingdom) often highlight gaps in APOS development, especially when students fail to transition smoothly between stages (e.g., from process to object). This framework can explain why some errors occur even in students who are adept at generating creative solutions but lack schema understanding.

~~There have been numerous studies done on error analysis. Research (Didiş Kabar & Erbaş, 2021) shows that students make mistakes in the four presented model problems. According to Polya, research from (Sukoriyanto et al., 2016) reveals that students continue to make errors when tackling permutation and combination problems. According to (Sari et al., 2018), the most common inaccuracy in representational abilities is problem-solving employing arithmetic symbols. According to research from (Khalid & Embong, 2019), errors that arise when completing common problems using integer operations are misconceptions. According to research from (Ozrecberoglu et al., 2022), student accomplishment in answering non-routine math tasks is low since errors occur frequently. Finally, according to the findings of (Jones et al., 2020), students had difficulties solving problems involving fractions.~~

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According to previous research findings, academics have yet to examine the types of errors ~~caused by~~ students make when answering contextual problems ~~on~~related to mathematical creative thinking ~~problems utilizing~~using APOS theory. This gap in the literature encouraged the researchers to conduct a study ~~in this area~~ to uncover and identify errors made by elementary school students when solving contextual problems that ~~required~~require creative thinking skills ~~using~~, utilizing APOS theory. By ~~using~~applying APOS theory, this study ~~seeks~~aims to identify students' errors in solving contextual ~~difficulties on~~problems related to creative thinking topics. The researchers chose ~~the~~ APOS theory because it ~~may~~can describe students' mental ~~actions~~processes in constructing mathematical concepts. Furthermore, this initial identification is critical for shaping students' creative thinking skills ~~so that~~, allowing for the development of relevant learning models based on ~~study~~the study's findings ~~may be constructed~~.

2. METHODS

2.1 Research Design

The exploratory descriptive approach is used in this study's qualitative investigation. ~~**When students**~~This approach aims to collect verbal data from students' responses when they complete a written test on contextual mathematical problems~~**, this approach aims to collect verbal data from their answers.**~~ In ~~**this study**~~addition, open-ended questions were used in interviews~~. **This is done**~~ to confirm the research subjects' responses. The issues addressed in this study include students' ~~**failures**~~difficulties in answering contextual mathematical problems ~~**on**~~related to creative thinking skills using the APOS theory (Action-Process-Object-Schema).

2.~~.~~2 Research Subject

The participants in this study were all sixth-grade students from ~~one of Cirebon Regency's~~a state elementary ~~schools. Because~~school in Cirebon Regency. Since not all students were ~~chosen~~selected as participants, ~~the research subjects were chosen using~~ a purposive ~~sample~~sampling technique~~.~~ was used to choose the research subjects. Fifty students ~~have~~had studied integer material. ~~In~~Within the allotted time, students ~~must~~were required to solve four contextual mathematical problems that ~~can test~~assessed their creative thinking skills. Based on the indicators of creative thinking ~~indications~~, all response papers were collected and ~~examined~~analyzed. Students who performed exceptionally well were not ~~chosen~~selected as subjects. On the other hand, students who ~~answered the sheet with~~made errors ~~in~~while solving contextual problems, including those involving numerical material, were considered research subjects. The research subjects were chosen based on the teacher's recommendation, specifically targeting students with good communication ~~abilities, so that data on student~~skills to facilitate the examination and identification of errors

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in handling contextual problems ~~on~~related to creative thinking skills ~~can be easily examined and found.~~. Two students were ~~chosen~~selected for interviews based on the teacher's recommendation.

2.3~~.~~ Research Instrument

The test and interviews used as research instruments have been construct-validated by two mathematics education experts. The primary purpose of these tests is to identify various errors made by students. The test comprises four contextual questions, specifically designed based on indicators of ~~students' creative thinking abilities. These indicators are based on the four characteristics of creative thinking according to (Kshetree et al., 2021): fluency, flexibility, originality, and elaboration.~~students' creative thinking abilities. These indicators are based on the four characteristics of creative thinking according to Kshetree et al. (2021): fluency, flexibility, originality, and elaboration. Interviews are conducted to gather additional information from ~~students'~~students' written response sheets. These interviews are unstructured, meaning that the researcher does not prepare specific questions in advance for the research subjects. Instead, students are expected to explain their responses during the interview. Interview questions are based on ~~students'~~students' answers on the test sheets. Finally, the researchers ~~confirms that~~ confirm the test answers with the interviewed students.

2.4~~.~~ Data Collection

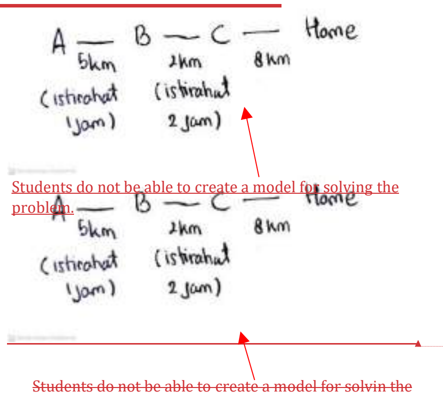
Data were collected from 40 students who completed a test consisting of four essay-style questions addressing contextual challenges related to mathematical creative thinking skills. Each student was given 40 minutes to ~~finish~~complete the test and submit their answer sheet. The researchers reviewed the responses, focusing on identifying common errors made by students. The researchers then collaborated with the class teacher to ~~pick~~select six students with strong communication skills for interviews. After selecting the research subjects, interviews were conducted to further corroborate ~~further responses from~~ the students' written responses. Interviews lasted 45 to 60 minutes, and all of them were recorded. APOS theory was used to conduct interviews for this study to ~~learn more about~~gain a deeper understanding of the ~~errors'~~errors students made when tackling challenges involving mathematical creativity in context. The researchers then independently assessed the outcomes of the student interviews. ~~-~~After selecting the research subjects, the researchers conducted interviews to further explore and clarify the ~~students'~~students' written responses. Each interview, lasting between 45 and 60 minutes, was fully recorded. Using APOS theory as a framework, the interviews aimed to gain deeper insights into the specific errors students made when approaching contextual challenges in mathematical creativity. The researchers then independently reviewed and ~~analysed~~analyzed the interview results. The next step involved data triangulation, achieved by comparing the results of the written test on contextual mathematical problems related to creative thinking skills with the interview insights gathered from both the researchers and students. Based on these triangulated results, the researchers derived their final findings.

2.5 Data Analysis

Data analysis began with validated transcripts of interviews, student work results, and field notes, using triangulation to ensure accuracy. ~~We used an~~An open, inductive thematic approach was employed for coding, mapping transcripts into categories based on the APOS framework. Initial codes were arranged alongside the text to facilitate analysis and were continuously refined to accurately represent ~~participants'~~participants' voices ~~accurately~~. Qualitative data coding requires diverse strategies depending on the intended analysis. After reviewing the research questions, further analytical coding was conducted, addressing the research questions through APOS framework themes in a comparative and ~~contracting~~contrasting manner to obtain multi-perspective analytical dimensions. ~~We carefully reviewed the~~The coded transcripts were carefully reviewed to ensure that statements and quotes ~~were~~ accurately ~~representative within~~represented the analysis. All ~~the~~ final coding decisions were guided by the research questions and my understanding of the data at hand.

3. RESULTS AND DISCUSSION

According to the Fluency indicator, Figure 1 shows the findings from the contextual problem-solving test of students' critical thinking skills. Figure 1(a) depicts students' responses in Indonesian, and Figure 1(b) depicts students' responses in English. The test results demonstrated that students could not meet the Fluency indicator when answering contextual mathematical problems ~~since~~, as they could not provide various solutions. This occurred because students did not comprehend how to solve the problems, causing themleading to make mistakes. It was most likely due to students' inability to comprehendunderstand the questions raisedposed in these tasks. As a result, interviews must bewere conducted to determineidentify students' errors in solving contextual problems related to questions on the Fluency indicator utilizingusing APOS theory.



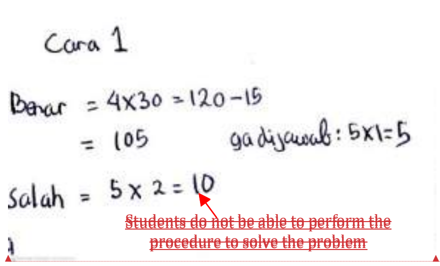
A ____ B ____ C ____ Home
5 km 2 km 8 km
1 hours 2 hours

(a) **(b)**

Figure 1 Students's answer: Students' answers on the Fluency indicator (a) Indonesian and (b) English.

The results of the interviews revealed that students made an interpretationinterpretive error. It was shown that students did not write down what they know andknew or what was requested in the response. Furthermore, students drew incorrect route drawingsdiagrams based on the problems in the questions. StudentsAlthough students could convert daily language into mathematical language, but they did not understand the meaning of the questions.

Figure 2 shows the results of the contextual problem-solving test of students' creative thinking skills, measured by the Flexibility indicator. Figure 2(a) depicts students' responses in Indonesian, while Figure 2(b) depicts students' responses in English. The test findings demonstrate that students did not meet the Flexibility indicator for solving contextual mathematical problems since, as they were unable to propose various solutions or approaches to the topic at hand. Furthermore, they cannotcould not present more than one approach or procedure for working on questions. ThatThis was most likely due to students' inability to understand the questions raised in answering these issues, causing them to make mistakes. As a result, interviews must bewere conducted to identify student errors in solving contextual problems using APOS theory.



Rule 1
True = 4x30=120-15 =105
Wrong : 5 x 2 = 10

Not Answer = 5 x 1 = 5

(a) **(b)**

Figure 2 Students' answer: Students' answers on the Flexibility indicators (a) Indonesian and (b) English.

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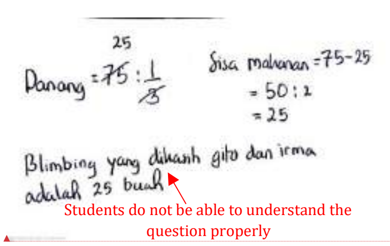
The interviews revealed that students made an ~~interpretation~~interpretive error. It was shown that- students did- not write down what they knew ~~and~~or what was- requested in the response. They could- convert daily language into mathematical language, but they did not- understand the significance of the questions. Students also made ~~mistakes on the concept too. It was proved~~ conceptual errors, as evidenced by ~~the~~a student applying the incorrect operating formula ~~on~~for integers. Furthermore, students ~~make~~made incorrect choices for the numbers ~~that are~~to be operated on in the problem. Students also made procedural errors because they could not fully explain ~~the~~their answers, ~~and~~as well as computational errors ~~as well~~. All of ~~the~~these errors were ~~proven by the answers of~~demonstrated in their responses to the problem.

Figure 3 illustrates the outcomes of the contextual problem-solving test of students' creative thinking skills, as measured by the Originality indicator. Figure 3(a) depicts students' responses in Indonesian, whereas Figure 3(b) depicts students' responses in English. The test findings demonstrate that students were unable to meet the Originality indicator when solving contextual mathematical problems because they ~~were unable to~~ could not convey fresh concepts that had not been previously ~~been~~ considered. This was- due to students' ~~incapacity~~inability to propose original ideas and their ~~inability~~failure to understand the questions ~~in answering~~when attempting to solve these problems. Using APOS theory, interviews were- conducted to identify student errors in solving contextual problems related to questions on the Originality indicator.



(a)

Danang = 75 : 1/3

Food left = 75 – 25
= 50 : 2
= 25

Startfruits given to Gito and Irma are 25.

(b)

Figure 3 ~~Students:~~ Students' answers on the originality indicator (a) Indonesian and (b) English.

The results of the interviews revealed that students ~~erred~~made errors in their understanding. They did not write down what they knew ~~and did not write down~~ or what was- requested in the response. Students could convert daily language into mathematical language, but they did not- understand the meaning- of the questions. Students also misunderstood the ~~concept as well. It is proven that students were~~concepts. This was demonstrated by their incorrect ~~in using~~use of formulas for fractional ~~operations~~ and integer arithmetic operations. Furthermore, students made incorrect choices for the numbers ~~that were~~ to be operated on in the problem. ~~Students~~They also made procedural errors ~~because~~, as they could not fully explain the answers they obtained, and ~~made~~ computational errors as well. Finally, it ~~has been proven~~was shown that students ~~were~~ provided incorrect ~~in their~~ final answers.

Figure 4 shows the results of the contextual problem-solving exam ~~of~~on students' creative thinking skills, as measured by the Elaboration indicator. Figure 4(a) ~~depicts~~presents students' responses in Indonesian, ~~whereas~~while Figure 4(b) ~~depicts students'~~ shows their responses in English.~~ ~~ The exam results ~~demonstrated~~indicated that students ~~could~~did not meet the Elaboration indicator ~~while~~when answering contextual mathematical problems because they ~~could not~~ were unable to develop ~~thoughts or~~ ideas ~~and~~or explain the problems ~~that~~they had ~~been~~ solved in detail. This ~~occurred~~ was due to students' failure to describe their answers in detail, ~~causing them~~which led to ~~make~~ mistakes. As a result, interviews must be conducted ~~utilizing~~using APOS theory to identify student ~~faults~~errors in solving contextual problems related to ~~questions on~~ the Elaboration indicator.

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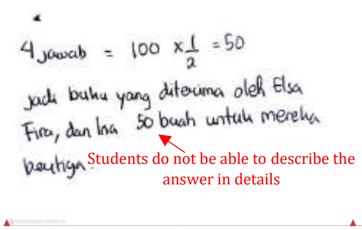

Answer: 100 x ½

= 50

~~Then,~~The books received by Elsa, Fira, and Lea approximately 50 books for all of them.

(a) (b)

Figure 4 ~~Students~~: Students' answers on the Elaboration indicator (a) Indonesian and (b) English.

The interviews revealed that students made ~~a mistake~~errors in their understanding. It was ~~shown~~evident that students did not write down what they knew ~~and did not write down~~or what was requested in the response. ~~Students~~ Although students could convert ~~daily~~everyday language into mathematical language, ~~but~~ they did not ~~understand~~fully grasp the significance of the questions. Students also made ~~mistakes on the concept too. It was proved~~conceptual errors, as evidenced by ~~the student applying~~ their incorrect application of the operating formula ~~on~~for integers. Furthermore, students ~~make~~made incorrect choices for the numbers ~~that are~~to be operated on in the problem. ~~Students also~~Additionally, students made procedural errors because they could not fully explain the answers they obtained, and they also made computational errors ~~as well~~.

~~Students with low mathematical creative thinking abilities were chosen as research subjects. This is because the students could not answer the four questions presented in contextual situations using the four indications of creative thinking abilities. Students' inability to attain indications of creative thinking skills in contextual mathematical problems was driven by a lack of familiarity with these types of questions (Ilhan & Akin, 2022; Kolar & Hodnik, 2021). In addition, students were only accustomed to challenges that did not necessitate using creative thinking skills. As a result, students must get acquainted with contextual difficulties that necessitate applying creative thinking skills (Rafiee & Abbasian-Naghneh, 2020; Yustina et al., 2022).~~

~~To handle contextual difficulties, students' creative thinking skills must be developed. One approach is to employ a learning model that requires students to participate in their learning in class. Material delivery must also focus on results, and problems must provide students with challenges relating to contextual problem. This is consistent with the research(Balakrishnan, 2022), which suggests that one strategy to promote creative thinking skills in elementary school students is to use teaching strategies that require students to be active in classroom learning and acquaint them with addressing complex challenges connected to learning. Furthermore, teachers must provide immediate supportive feedback to students that allows students to actively find their answers so that students do not struggle to solve contextual problems(Kim et al., 2022).~~

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To handle contextual difficulties, students' creative thinking skills must be developed. One approach is to employ a learning model that requires students to actively participate in their learning in class. Material delivery must also focus on outcomes, and problems must provide students with challenges related to contextual problems. This is consistent with research by Balakrishnan (2022), which suggests that one strategy to promote creative thinking skills in elementary school students is to use teaching strategies that require students to be active in classroom learning and familiarize them with addressing complex challenges connected to learning. Furthermore, teachers must provide immediate supportive feedback to students, allowing them to actively find their answers so that students do not struggle to solve contextual problems (Kim et al., 2022).

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In sixth-grade elementary school, two students with low creative thinking ~~skill make~~skills made mistakes when answering contextual mathematical problems. Students' common errors in solving contextual problems requiring creative thinking abilities can be divided into four categories: interpretation errors, conceptual errors, procedural errors, and computational/technical errors. Students' interpretation errors occur when they fail to understand the topic or problem in the given context. They are unable to grasp the significance of the questions posed to them. Based on the four questions ~~given~~provided, students could not ~~put~~write down what was~~-~~ known and what was~~-~~ asked in the question, ~~causing students~~leading them to misinterpret the meaning.

Furthermore, in question one, the student incorrectly described the sketch of the route image based on the difficulty of the problem. ~~Students~~The student created~~-~~ a route using only straight lines, although the question stated that the path should return to the starting position because Budi returns to the origin. ~~Students were~~The student was also incorrect in their findings in response to the inquiry. ~~Students~~They made errors in responding correctly to the presented contextual difficulties based on the four questions. ~~Students also~~Additionally, the students did~~-~~ not fully comprehend the questions presented. This was~~-~~ due to ~~students'~~their inability to define or comprehend sketch drawings in a specific topic ~~(Özdemir & Dede, 2022).~~(Özdemir & Dede, 2022).

Students committed conceptual errors, such as incorrectly applying the formula for arithmetic operations with mixed integers. In question ~~number~~ two, the students ~~did~~ performed arithmetic operations on integers without considering which ~~rule was stronger~~operation takes precedence between addition, subtraction, multiplication, and division~~ operations causing them~~, which led to ~~perform incorrectly. Students~~ incorrect results. The students also misunderstood the division process of numbers in question ~~number~~ two. In response to question ~~number~~ two, the students answered $75 \div \frac{1}{3}$. ~~P~~ In this question, the students crossed out the numbers 75 and 3~~. It was shown~~, showing that ~~the students~~they had a wrong ~~idea~~understanding of division and multiplication operations. The correct ~~notion was~~concept is $75 \div \frac{1}{3} = 75 \times 3$. Additionally, students ~~choose~~chose the incorrect number to operate on in the problem. This was~~-~~ because ~~students~~they did~~-~~ not fully comprehend what was~~-~~ being ~~requested~~asked in the problem, causing numbers that did~~-~~ not need to be operated on to become operational ~~(Joung & Kim, 2022).~~ (Joung & Kim, 2022).

~~Based on the four questions, students experienced errors in choosing the numbers to operate in the questions. This is due to students' failure to read the questions carefully, resulting in students misunderstanding what the questions signify. This demonstrates that students' knowledge of mathematical concepts remains low. This is reinforced by (Karakuş et al., 2022), which indicates that their conceptual comprehension is poor when students answer specific mathematical problems. As a result, students make conceptual errors. The finding is supported by study (Tooher & Johnson, 2020), which found that students struggle to grasp particular mathematical topics if they do not understand the ideas relevant to the studied issues. Students will make mistakes when answering problems, particularly contextual ones. Conceptual errors can also develop as a result of prior knowledge. This is consistent with the findings of a study (Jarrah et al., 2022), which found that students' conceptual errors are also caused by prior mathematical learning. For example, students are unable to comprehend integer concepts since merely memorize integer formulas without applying the concept and how to apply them. As a result, students struggle to gain a correct and comprehensive comprehension of a concept (Barbieri & Booth, 2020).~~

Based on the four questions, students experienced errors in choosing the numbers to operate on. This was due to their failure to read the questions carefully, which led to misunderstandings of what the questions actually signified. This demonstrates that students' understanding of mathematical concepts remains low. This is supported by Karakuş et al. (2022), who indicate that students' conceptual comprehension is poor when answering specific mathematical problems. As a result, students make conceptual errors. The finding is supported by a study by Tooher and Johnson (2020), which found that students struggle to grasp particular mathematical topics if they do not understand the concepts relevant to the studied issues. Students will make mistakes when answering problems, particularly contextual ones. Conceptual errors can also develop as a result of prior knowledge. This is consistent with the findings of a study by Jarrah et al. (2022), which found that students' conceptual errors are also caused by prior mathematical learning. For example, students are unable to comprehend integer concepts because they merely memorize integer formulas without understanding the concept or how to apply them. As a result, students struggle to gain a correct and comprehensive understanding of the concept (Barbieri & Booth, 2020).

Students made~~-~~ procedural errors, including failing to explain the steps on the answer sheet adequately. ~~Students~~ In question one, students only mentioned~~-~~ the outcome ~~in question number one. Students~~and were unable to explain the methods ~~taken~~used to ~~acquire~~obtain the answer ~~from number one~~. Then, ~~on problems 2~~in questions two and ~~3~~three, students could explain the ~~phases of the response~~steps involved, but only partially ~~because the~~, as their final answers were~~-~~ incorrect. The students could not clarify their answers to question four because they misinterpreted the significance of the ~~questions~~question. Furthermore, students were incorrect in concluding the results of the given problem. This was demonstrated ~~by~~in question five, ~~in which~~where students assumed~~-~~ that the books delivered to Elsa, Fira, and Ina were all the same ~~as~~, totaling 50 books. The problem fails to indicate that ~~Elsa, Fira, and Ina's~~the book distribution among Elsa, Fira, and Ina was~~-~~ the same ~~amount~~. As a result, students did~~-~~ not understand the significance of the problem, and their conclusions were incorrect. Students were also incorrect in executing integer operations when solving problems, even though they had reached the ~~proper~~correct conclusions. Therefore, students need to apply all the principles required to answer the problem to avoid ~~making~~ errors in determining the outcome ~~(Hu et al., 2022).~~(Hu et al., 2022). Students must be able to present valid mathematical ~~reasons~~reasoning, draw conclusions, and develop generalizations in order to solve ~~a specific mathematical problem(Köğce, 2022).~~specific mathematical problems (Köğce, 2022).

~~Students' technical or computational errors happened during the calculation procedure. For example, it could be discovered in the procedure of multiplying integers in problem number two. The student carries out the operation $6 \times (-1) = -5$. The conclusions of these calculations were incorrect; hence students' final answers to the problems were incorrect. This was consistent with the study's findings(Khalid & Embong, 2019), which found that most students had broad misconceptions regarding integer operations, such as the multiplication of positive and negative integers. Errors in dividing integers by fractions occured because students were less attentive while performing operations. As a result, a technical error happened. For example, in question three, students completed the operation $75 \div \frac{1}{3} = 25$. The outcomes of these calculations were inaccurate, causing students to conclude the final answer to the presented questions incorrectly. According to the study, the most common mistakes students make in the operation of dividing integers are those who are negligent in using the methods of the problems supplied (Üzel, 2018). As a result, students must have strong fundamental mathematical problem-solving abilities to solve contextual mathematical problems (Sternberg et al., 2021). This is essential to ensure that students' mistakes do not reoccur.~~

~~According to the findings, sixth-grade students were still in the action stage of the APOS theory. This occurs because students~~ Students' technical or computational errors occurred during the calculation procedure. For example, this can be observed in the process of multiplying integers in problem number two. The student carried out the operation 6 × (-1) = -5. The conclusions of these calculations were incorrect, resulting in incorrect final answers to the problems. This finding aligns with the study by Khalid and Embong (2019), which found that most students had broad misconceptions regarding integer operations, such as the multiplication of positive and negative integers. Errors in dividing integers by fractions occurred because students were less attentive while performing operations. As a result, a technical error occurred. For example, in question three, students completed the operation $75 \div \frac{1}{3} = 25$. The outcomes of these calculations were inaccurate, causing students to conclude the final answer to the presented questions incorrectly. According to the study, the most common mistakes students make in the operation of dividing integers are those who are negligent in using the methods provided in the problems (Üzel, 2018). As a result, students must have strong fundamental mathematical problem-solving abilities to solve contextual mathematical problems (Sternberg et al., 2021). This is essential to ensure that students' mistakes do not reoccur.

According to the findings, sixth-grade students were still in the action stage of the APOS theory. This occurs because students lack an APOS conceptual structure, ~~causing~~which causes them to make errors when faced with contextual mathematical problems. For example, students have trouble implementing integer operations due to a lack of conceptual structure ~~connected to the process, object, and schema stages(Kshetree et al., 2021).~~related to the process, object, and schema stages (Kshetree et al., 2021). This demonstrates that students cannot manage the application of theorems and formulas required for specific mathematical problems. Based on the APOS theory analysis ~~findings~~, students have difficulties understanding the ~~idea~~concept of operations on numbers. This is because ~~when the students were~~, at the previous level, ~~they~~students could not understand the ~~notion~~concept of operations on integers, ~~causing~~which caused them to make errors in solving the problems presented. Students only memorize formulas, so they struggle when ~~they learn~~learning about the ~~idea~~concept of operations on integers.

In addition, students lack experience understanding integer operations, do not fully understand the concept of integer operations, and have minimal prior knowledge of integer operations ~~at~~from the previous level. As a result, teachers must have an effective strategy to identify student errors. One technique for reducing student errors in handling contextual problems is to hold open discussions ~~focusing on efforts to overcome student errors during the learning process (Ilhan & Akin, 2022).~~that focus on efforts to overcome student errors during the learning process (İlhan & Akin, 2022).

~~Assessing and analyzing students' errors in completing contextual problems on creative thinking skills is considered an essential tool for learning(Rahayuningsih et al., 2021). Furthermore, it is indicated that to overcome cognitive obstacles in solving difficulties presented in learning mathematics, and students must have a positive mindset and optimal thinking activities that activate prior knowledge and experience in solving specific problems. Since students in different courses differ in their capacities for creative thought, the understanding of particular students should be considered while designing a teacher's thinking activity(Jumadi et al., 2020).~~

~~These findings suggest that teachers should appropriately prepare students on the classroom's procedural and conceptual parts of mathematics. Both features are critical in comprehending mathematical material (Barbieri & Booth, 2020). Identifying students' errors in addressing contextual mathematical problem and the skill to think creatively on integer operations has helped teachers recognize students' shortcomings. This will assist the teacher in preparing classroom activities and addressing errors that occur. Students' errors are caused by a lack of creative thinking skills when tackling contextual mathematical problems. According to (Tooher & Johnson, 2020), a student with low notions in creative thinking skills will make mistakes in solving the problem. Therefore, students' skill to think creatively must be developed so that similar errors will not occur again. After improving their creative thinking skills, students will develop their own formulas or principles for solving mathematical problems. According to the research, strengthening mathematical creative thinking skills would allow students to pay attention to all components required to assist in solving mathematical problems, allowing them to find formulas or rules on their own (Foster, 2021).~~

Assessing and analyzing students' errors in completing contextual problems on creative thinking skills is considered an essential tool for learning (Rahayuningsih et al., 2021). Furthermore, it is indicated that to overcome cognitive obstacles in solving difficulties presented in mathematics learning, students must have a positive mindset and engage in optimal thinking activities that activate prior knowledge and experience in solving specific problems. Since students in different courses differ in their capacities for creative thought, the understanding of individual students should be considered while designing a teacher's thinking activity (Jumadi et al., 2020).

These findings suggest that teachers should appropriately prepare students on both the procedural and conceptual aspects of mathematics. Both features are critical in comprehending mathematical material (Barbieri & Booth, 2020). Identifying students' errors in addressing contextual mathematical problems and their ability to think creatively about integer operations has helped teachers recognize students' shortcomings. This will assist teachers in preparing classroom activities and addressing errors that occur. Students' errors are caused by a lack of creative thinking skills when tackling contextual mathematical problems. According to Tooher and Johnson (2020), a student with low skills in creative thinking will make mistakes in solving the problem.

Therefore, students' ability to think creatively must be developed so that similar errors do not occur again. After improving their creative thinking skills, students will be able to develop their own formulas or principles for solving mathematical problems. According to the research, strengthening mathematical creative thinking skills would allow students to pay attention to all components required to solve mathematical problems, enabling them to discover formulas or rules on their own (Foster, 2021).

4. CONCLUSSION

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Based on the research results and discussion, it concludescan be concluded that the students selected for the study did not meet the four creative thinking markersindicators of fluency, flexibility, originality, and elaboration. This incapacity was caused by errors made by students when tackling contextual problem-solving difficulties usingtasks that required creative thinking skills. According to the APOS theory, student errors include: (1) Misinterpretation errors: incorrectly converting the questions into mathematical language/symbols and misinterpreting the given questions; (2) Conceptual errors: students misused formulas while countingwhen working with fractions and integers. Furthermore, students made wrongincorrect choices for the numbers that were operated on in the problem; (3) Procedural error: the student errors: students improperly concluded the question. This was occurred because students failed to pay attention to what was asked in the question and were incorrect in carrying out the processes needed to solve the problem because students , as they were unable to explain the solutions they had received.; (4) Technical/computingcomputational errors: students made errorsmistakes in computations involving integer operations, and students'their final answers to the questions they worked on were incorrect.

Future studystudies should lead tofocus on the development of new learning models capable of improving mathematical creative thinking skills. This is significant because research shows that kidsstudents with strong creative thinking skills adapt fastquickly to new issuesproblems. On the other hand, students who lack creative thinking skills will have difficulty solving an issue.struggle to solve problems. Future research should investigateexplore how students think while tackling contextual problems in mathematics. Identifying students' cognitive processes will help them gain a better grasp becauseunderstanding, as they take a particular approach to problem-solving. in specific ways. When teachers understand their students' thought processes, they can quickly identify students' challenges quickly whenin solving mathematical problems. As a result, the teacher can modifyadjust the learning paradigmapproach for the next meetingfuture lessons.

REFERENCES

Al-Jarf, R. (2022). Student-Interpreters' Foreign Proper Noun Pronunciation Errorsinterpreters' foreign proper noun pronunciation errors in English-Arabic and Arabic-English Media Discourse Interpreting. media discourse interpreting. *International Journal of Translation and Interpretation Studies, 2*(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11https://doi.org/10.32996/ijtis.2022.2.1.11

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature Review :review: Mathematical Creative Thinking Ability ,creative thinking ability and Students ' Self Regulated Learningstudents' self-regulated learning to Useuse an Open Ended Approach. open-ended approach. *Malikussaleh Journal of Mathematics Learning, 4*(1), 52–61.

Ammaralikit, A., & Chattiwat, W. (2020). Effects of Business Reading Modelthe business reading model on Thai Learners' Readinglearners' reading and Creative Thinking Abilities. creative thinking abilities. *English Language Teaching, 13*(5), 191. https://doi.org/10.5539/elt.v13n5p191https://doi.org/10.5539/elt.v13n5p191

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? *International Journal of Instruction, 14*(3), 175–186. https://doi.org/10.29333/iji.2021.14310a https://doi.org/10.29333/iji.2021.14310a

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: a study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education*, *32*(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on display: Incorrect examples refine equation solving and algebraic feature knowledge. *Applied Cognitive Psychology*, *34*(4), 862–878. https://doi.org/10.1002/acp.3663

Barkai, R. (2021). Using cases as a means to discuss errors in mathematics teacher education. *Education Sciences*, *11*(10). https://doi.org/10.3390/educsci11100575

Bintoro, H. S., Walid, & Mulyono. (2021). The Spatial Thinking Processspatial thinking process of the Field-Independent Studentsfield-independent students based on Action-Process-Object-Schema Theor. the action-process-object-schema theory. *European Journal of Educational Research, 10*(4), 1807–1823.

Boz-Yaman, B., & Yiğit Koyunkaya, M. (2019). Examination of Prepre-service Mathematics Teachers' Mental Constructionsmathematics teachers' mental constructions of Function Transformation. function transformation. *Acta Didactica Napocensia, 12*(1), 33–56. https://doi.org/10.24193/adn.12.1.3 https://doi.org/10.24193/adn.12.1.3

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Cho, M. K., & Kim, M. K. (2020). Investigating elementary students' problem solving and teacher scaffolding in solving an Ill-structured problem. *International Journal of Education in Mathematics, Science and Technology*, *8*(4), 274–289. https://doi.org/10.46328/IJEMST.V8I4.1148

Cooper, A. A. (2021). Incorporating ~~Critical~~critical and ~~Creative Thinking~~creative thinking in a ~~Transitions Course.~~ transitions course. *Primus, 31*(9), 995–1006. ~~https://doi.org/10.1080/10511970.2020.1805659~~ https://doi.org/10.1080/10511970.2020.1805659

Didiş Kabar, M. G., & Erbaş, A. K. (2021). Pre-service secondary mathematics teachers' anticipation and identification of students' thinking in the context of modelling problems. *International Journal of Mathematical Education in Science and Technology*, *52*(2), 208–236. https://doi.org/10.1080/0020739X.2019.1670368

Emara, M., Hutchins, N. M., Grover, S., Snyder, C., & Biswas, G. (2021). Examining student regulation of collaborative, computational, problem-solving processes in openended learning environments. *Journal of Learning Analytics*, *8*(1), 49–74. https://doi.org/10.18608/JLA.2021.7230

Faizah, S., Nusantara, T., Sudirman, & Rahardi, R. (2022). Constructing ~~Students' Thinking Process~~students' thinking process through ~~Assimilation~~assimilation and ~~Accommodation Framework.~~ accommodation framework. *Mathematics Teaching-Research Journal, 14*(1), 253–269.

Fonteles Furtado, P. G., Hirashima, T., Hayashi, Y., & Maeda, K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. *Research and Practice in Technology Enhanced Learning*, *14*(1), 1–18. https://doi.org/10.1186/s41039-019-0096-1

Foster, M. K. (2021). Design ~~Thinking~~thinking: A ~~Creative Approach~~creative approach to ~~Problem Solving.~~ problem solving. *Management Teaching Review, 6*(2), 123–140. ~~https://doi.org/10.1177/2379298119871468~~ https://doi.org/10.1177/2379298119871468

Haghverdi, M., & Wiest, L. R. (2016). The ~~Effect~~effect of ~~Contextual~~contextual and ~~Conceptual Rewording~~conceptual rewording on ~~Mathematical Problem- Solving Performance.~~ mathematical problem-solving performance. *The Mathematics Educator, 25*(1), 56–73.

Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient approach to teach literary sociology. *International Journal of Instruction*, *12*(1), 283–298. https://doi.org/10.29333/iji.2019.12119a

Hu, Q., Son, J. W., & Hodge, L. (2022). Algebra ~~Teachers' Interpretation~~teachers' interpretation and ~~Responses~~responses to ~~Student Errors~~student errors in ~~Solving Quadratic Equations.~~ solving quadratic equations. *International Journal of Science and Mathematics Education, 20*(3), 637–657. ~~https://doi.org/10.1007/s10763-021-10166-1~~ https://doi.org/10.1007/s10763-021-10166-1

Hunukumbure, A. D., Horner, P. J., Fox, J., & Thakerar, V. (2021). An online discussion between students and teachers: a way forward for meaningful teacher feedback? *BMC Medical Education*, *21*(1), 1–9. https://doi.org/10.1186/s12909-021-02730-8

Ilhan, A., & Akin, M. F. (2022). Analysis of ~~Contextual Problem Solutions, Mathematical Sentences~~contextual problem solutions, mathematical sentences, and ~~Misconceptions~~misconceptions of ~~Pre-Service Mathematics Teachers.~~ pre-service mathematics teachers. *International Electronic Journal of Mathematics Education, 17*(1), em0666. ~~https://doi.org/10.29333/iejme/11470~~ https://doi.org/10.29333/iejme/11470

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(6). https://doi.org/10.29333/ejmste/12070

Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. *School Science and Mathematics*, *120*(4), 232–243. https://doi.org/10.1111/ssm.12402

Joung, E., & Kim, Y. R. (2022). Identifying ~~Preservice Teachers' Concept~~preservice teachers' concept-based and ~~Procedure~~procedure-based ~~Error~~error patterns in ~~Multiplying~~multiplying and ~~Dividing Decimals.~~ dividing decimals. *International Journal of Education in Mathematics, Science and Technology, 10*(3), 549–567. ~~https://doi.org/10.46328/ijemst.2227~~ https://doi.org/10.46328/ijemst.2227

Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE)*, *9*(2), 415–420. https://doi.org/10.11591/ijere.v9i2.20531

Junaedi, Y., Wahyudin, & Juandi, D. (2021). Mathematical creative thinking ability of junior high school students' on polyhedron. *Journal of Physics: Conference Series*, *1806*(1), 36–45. https://doi.org/10.1088/1742-6596/1806/1/012069

Karakuş, D., Özkaya, M., & ~~Konyaliglu~~Konyalıoğlu, A. C. (2022). ~~Geogebra~~GeoGebra in the ~~Correction~~correction and ~~Understanding~~understanding of ~~Errors Regarding~~errors regarding the ~~Concept~~concept of ~~Asymptote.~~ asymptote. *Shanlax International Journal of Education, 10*(2), 67–79. ~~https://doi.org/10.34293/education.v10i2.4400~~ https://doi.org/10.34293/education.v10i2.4400

Kenney, R., An, T., Kim, S. H., Uhan, N. A., Yi, J. S., & Shamsul, A. (2020). Linear ~~Programming Models~~programming models: Identifying ~~Common Errors~~common errors in ~~Engineering Students' Work~~engineering students' work with ~~Complex Word Problems.~~complex word problems. *International Journal of Science and Mathematics Education, 18*(4), 635–655. ~~https://doi.org/10.1007/s10763-019-09980-5~~https://doi.org/10.1007/s10763-019-09980-5

Khalid, M., & Embong, Z. (2019). Sources and ~~Possible Causes~~possible causes of ~~Errors~~errors and ~~Misconceptions~~misconceptions in ~~Operations~~operations of ~~Integers~~integers. *International Electronic Journal of Mathematics Education, 15*(2). ~~https://doi.org/10.29333/iejme/6265~~https://doi.org/10.29333/iejme/6265

Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of ~~Scaffolding~~scaffolding on ~~Information Literacy~~information literacy and ~~Argumentation Skills~~argumentation skills in ~~Virtual Field Trips~~virtual field trips and ~~Problem-Based Learning~~problem-based learning for ~~Scientific Problem Solving.~~scientific problem solving. *International Journal of Science and Mathematics Education, 20*(2), 215–236. ~~https://doi.org/10.1007/s10763-020-10145-y~~https://doi.org/10.1007/s10763-020-10145-y

Köğce, D. (2022). Examination of ~~Mathematical Errors~~mathematical errors and ~~Mistakes~~mistakes in ~~Calculus Course.~~calculus course. *Educational Policy Analysis and Strategic Research, 17*(1), 295–311. ~~https://doi.org/10.29329/epasr.2022.248.15~~https://doi.org/10.29329/epasr.2022.248.15

Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. *European Journal of Educational Research*, *10*(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467

Konrad, M., Editor, A., & Smith, J. E. (2021). ~~*Creative Self-Efficacy : An Essential Transition Skill for Students With Learning Disabilities*. https://doi.org/10.1177/10534512211024938~~Creative self-efficacy: An essential transition skill for students with learning disabilities. https://doi.org/10.1177/10534512211024938

Kshetree, M. P., Acharya, B. R., Khanal, B., & Panthi, R. K. (2021). Eighth ~~Grade Students' Misconceptions~~grade students' misconceptions and ~~Errors~~errors in ~~Mathematics Learning~~mathematics learning in Nepal. *European Journal of Educational Research, 10*(4), 1907–1918.

Lien, N. T. N., Khuyen, N. T. T., Tho, N. T., Hoa, N. N., Hanh, N. T., Tho, C. C., Hai, T. D., & Van Bien, N. (2021). Teachers' feelings of safeness in school-family-community partnerships: Motivations for sustainable development in moral education. *International Journal of Evaluation and Research in Education*, *10*(1), 97–107. https://doi.org/10.11591/ijere.v10i1.20798

Moon, K. (2019). ~~PRESERVICE TEACHERS? UNDERSTANDING OF TWO-VARIABLE INEQUALITIES: APOS THEORY.~~Preservice teachers' understanding of two-variable inequalities: APOS theory. *Proceedings of the 41st Annual Meeting of PME-NA*, 686–694.

Moru, E. K. (2020). An APOS ~~Analysis~~analysis of ~~University Students' Understanding~~university students' understanding of ~~Derivatives~~derivatives: A Lesotho ~~Case Study~~case study. *African Journal of Research in Mathematics, Science and Technology Education, 0*(0), 1–14. ~~https://doi.org/10.1080/18117295.2020.1821500~~https://doi.org/10.1080/18117295.2020.1821500

Ndiung, S., Sariyasa, J., Jehadus, E., & Apsar, R. A. (2021). The ~~Effect~~effect of Treffinger ~~Creative Learning Model~~creative learning model with the ~~Use~~use of RME ~~Principles~~principles on ~~Creative Thinking Skill~~creative thinking skills and ~~Mathematics Learning Outcome~~mathematics learning outcomes. *International Journal of Instruction, 14*(2), 873–888.

Nugroho, A. A., Nizarudin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students ' creative thinking in the use of representations in solving mathematical problems based on cognitive style. *Journal of Research and Advances in Mathematics Education*, *5*(2), 202–217. https://doi.org/10.23917/jramathedu.v5i2.9983

Nwoke, B. L. (2021). Enhancing primary school pupils ' mathematics creative ability through activity based learning approach. *Malikussaleh Journal of Mathematics Learning (MJML)*, *4*(2), 70–76.

Özdemir, E., & Dede, E. (2022). ~~INVESTIGATION OF THE WAYS PROSPECTIVE MATHEMATICS TEACHERS RESPOND TO STUDENTS ' ERRORS : AN EXAMPLE OF OF THE EQUAL SIGN.~~Investigation of the ways prospective mathematics teachers respond to students' errors: An example of the equal sign. *International Online Journal of Education and Teaching (IOJET), 9*(2), 723–739.

Ozrecberoglu, N., Aydın, S., & Aydın, O. (2022). Students' ~~Skills In Solving Non-Routine Mathematical~~

~~Problems.~~skills in solving non-routine mathematical problems. *Education Quarterly Reviews, 5*(2), 446–461. ~~https://doi.org/10.31014/aior.1993.05.02.504~~https://doi.org/10.31014/aior.1993.05.02.504

Peltier, C., & Peltier, T. K. (2020). Mining ~~Instruction From Student Mistakes~~instruction from student mistakes: Conducting an ~~Error Analysis~~error analysis for ~~Mathematical Problem Solving.~~mathematical problem solving. *Beyond Behavior, 29*(3), 141–151. ~~https://doi.org/10.1177/1074295620903050~~https://doi.org/10.1177/1074295620903050

Prayitno, A. T., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2022). Identification of graph thinking in solving mathematical problems naturally. *Participatory Educational Research*, *9*(2), 118–135. https://doi.org/10.17275/per.22.32.9.2

Puspitasari, L., In, A., & Syaifuddin, M. (2019). ~~Analysis of Students ' Creative Thinking in Solving Arithmetic Problems. *INTERNATIONAL ELECTRONIC JOURNAL OF MATHEMATICS EDUCATION*~~Analysis of students' creative thinking in solving arithmetic problems. *International Electronic Journal of Mathematics Education*, *14*(1), 49–60.

Rafiee, M., & Abbasian-Naghneh, S. (2020). Willingness to ~~Write~~write (WTW): Development of a model in EFL writing classrooms. *Cogent Education, 7*(1), ~~0~~1–16. ~~https://doi.org/10.1080/2331186X.2020.1847710~~https://doi.org/10.1080/2331186X.2020.1847710

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. *Participatory Educational Research*, *8*(3), 285–299. https://doi.org/10.17275/per.21.66.8.3

Santia, I., Purwanto, Sutawidjadja, A., Sudirman, & Subanji. (2019). Exploring mathematical representations in solving ill-structured problems: The case of quadratic function. *Journal on Mathematics Education*, *10*(3), 365–378. https://doi.org/10.22342/jme.10.3.7600.365-378

Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with react strategy in solving the problems of mathematical representation ability. *Journal on Mathematics Education*, *9*(1), 121–128. https://doi.org/10.22342/jme.9.1.4378.121-128

Soneira, C. (2022). The ~~Use~~use of ~~Representations~~representations when ~~Solving Algebra Word Problems~~solving algebra word problems and the ~~Sources~~sources of ~~Solution Errors.~~solution errors. *International Journal of Science and Mathematics Education, 20*(5), 1037–1056. ~~https://doi.org/10.1007/s10763-021-10181-2~~https://doi.org/10.1007/s10763-021-10181-2

Sternberg, R. J., Glaveanu, V., Karami, S., Kaufman, J. C., Phillipson, S. N., & Preiss, D. D. (2021). Meta-intelligence: understanding, control, and interactivity between creative, analytical, practical, and wisdom-based approaches in problem solving. *Journal of Intelligence*, *9*(2). https://doi.org/10.3390/jintelligence9020019

Sukoriyanto, S., Nusantara, T., Subanji, S., & Chandra, T. D. (2016). Students' ~~Errors~~errors in ~~Solving~~solving the ~~Permutation~~permutation and ~~Combination Problems Based~~combination problems based on ~~Problem Solving Steps~~problem-solving steps of Polya. *International Education Studies, 9*(2), 11. ~~https://doi.org/10.5539/ies.v9n2p11~~https://doi.org/10.5539/ies.v9n2p11

Tatira, B. (2021). Mathematics ~~Education Students' Understanding~~education students' understanding of ~~Binomial Series Expansion Based~~binomial series expansion based on the APOS ~~Theory~~theory. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(12), 1–13. ~~https://doi.org/10.29333/EJMSTE/11287~~https://doi.org/10.29333/EJMSTE/11287

Tooher, H., & Johnson, P. (2020). The role of analogies and anchors in addressing students' misconceptions with algebraic equations. *Issues in Educational Research*, *30*(2), 756–781.

Üzel, D. (2018). Investigation of misconceptions and errors about division operation in fractions. *Universal Journal of Educational Research*, *6*(11), 2656–2662. https://doi.org/10.13189/ujer.2018.061131

Van Melle, J., & Ferreira, M. (2022). Developing ~~Students' Intercultural Sensitivity~~students' intercultural sensitivity at the ~~Home Campus~~home campus: An ~~Innovative Approach Using~~innovative approach using the ~~Theory~~theory of the ~~Creative Action Methodology Pedagogy.~~creative action methodology pedagogy. *Teaching and Learning Inquiry, 10*, 1–23. ~~https://doi.org/10.20343/TEACHLEARNINQU.10.12~~https://doi.org/10.20343/TEACHLEARNINQU.10.12

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yustina, Mahadi, I., Ariska, D., Arnentis, & Darmadi. (2022). The ~~Effect~~effect of ~~E-Learning Based~~e-learning based on the ~~Problem-Based Learning Model~~problem-based learning model on ~~Students' Creative~~

~~Thinking Skills During~~students' creative thinking skills during the ~~Covid~~COVID-19 ~~Pandemic~~pandemic. *International Journal of Instruction, 15*(2), 329–348. ~~https://doi.org/10.29333/iji.2022.15219a~~https://doi.org/10.29333/iji.2022.15219a

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TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF CONFIRMATION: PROOFREADING SERVICE

This is to certify that the artile for **"MATHEMATICAL CREATIVE THINKING SKILL: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS"** by Khoerul Umam has been edited by our team on 09 December 2024.

For any enquiries, please contact us at the Professional Development Unit, School of Languages, Civilisation and Philosophy (04-9285696) or email editorslcp@uum.edu.my

Thank you.

"SCHOLARSHIP, VIRTUE AND SERVICE"

Yours sincerely,

Mrs. Nur Syuhada binti Jamaludin
Coordinator
Editing and Translation Services

Mrs. Roshita binti Che Ani
Administrative Assistant (P/O)

Bukti Konfirmasi Artikel Accepted

13 Desember 2024

Uhamka
UNIVERSITAS MUHAMMADIYAH PROF. DR. HAMKA

Khoerul Umam <khoerul.umam@uhamka.ac.id>

[HASSS_2024_0314] letter of publication

2 messages

HASSS Journal <hasss.manager@su.ac.th> Fri, Dec 13, 2024 at 10:01 AM
To: "khoerul.umam@uhamka.ac.id" <khoerul.umam@uhamka.ac.id>
Cc: Chief Editor of HASSS Journal <hasss.editor@su.ac.th>

Ref: HASSS_2024_0314
Title: “Mathematical Creative Thinking Skills: Using APOS Theory to Identify Student Errors in Solving Contextual Problems”
Journal: *Humanities, Arts and Social Sciences Studies (HASSS)*

Dear Khoerul Umam,

We are pleased to inform you that your paper has been accepted for publication, it will proceed to copy-editing and production. Please find the attached letter of publication.

Thank you for submitting your work to *Humanities, Arts and Social Sciences Studies*. We hope you consider us again for future submission.

Kind regards,

Korakoch Attaviriyanupap
Editor-in-Chief
Humanities, Arts and Social Sciences Studies (HASSS)

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Khoerul Umam <khoerul.umam@uhamka.ac.id> Fri, Dec 13, 2024 at 12:39 PM
To: HASSS Journal <hasss.manager@su.ac.th>

Thank you so much for the great news!
[Quoted text hidden]

Humanities, Arts and Social Sciences Studies

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December 13, 2024

Dear Khoerul Umam, Ardi Dwi Susandi, Muhammad Irfan, Mohd lsha Bin Awang, Eka Nana Susanti, and Supandi,

Your research article entitled "Mathematical Creative Thinking Skills: Using APOS Theory to Identify Student Errors in Solving Contextual Problems" has been accepted for publication in Humanities, Arts and Social Sciences Studies.

Thank you for your contribution to Humanities, Arts and Social Sciences Studies.

Sincerely yours,

(Professor Korakoch Attaviriyanupap, Ph.D.)
Editor-in-Chief of Humanities, Arts and Social Sciences Studies

Bukti konfirmasi Proofs for ready

19 Januari 2025

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[HASSS] Editor Decision

1 message

Parichat Chaisawas via Thai Journals Online (ThaiJO) <admin@tci-thaijo.org> Tue, Jan 19, 2025 at 9:30 AM
Reply-To: Parichat Chaisawas <hasss.manager@su.ac.th>
To: Khoerul Umam <khoerul.umam@uhamka.ac.id>, Ardi Dwi Susandi <ardi.official@ecampus.ut.ac.id>, Muhammad Irfan <muhammadirfan@uny.ac.id>, Mohd Isha Bin Awang <isha@uum.my.edu>, Eka Nana Susanti <eka_nana@uhamka.ac.id>, Supandi <supandi@uhamka.ac.id>

Dear Khoerul Umam, Ardi Dwi Susandi, Muhammad Irfan, Mohd Isha Bin Awang, Eka Nana Susanti, Supandi,

The editing of your submission, "Mathematical creative thinking skills: Using APOS theory to identify student errors in solving contextual problems," is complete. We are now sending it to production.

Submission URL: https://so02.tci-thaijo.org/index.php/hasss/authorDashboard/submission/269211

Parichat Chaisawas

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Research Article

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MATHEMATICAL CREATIVE THINKING SKILLS: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS

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ABSTRACT

Individuals with strong creative thinking abilities are particularly adept at effectively addressing mathematical contextual problems. However, students often need more vital creative thinking skills in the classroom, frequently due to errors they make themselves. This study aims to identify students' specific errors when solving contextual problems related to integer operations. This research adopts a qualitative approach, using an exploratory and descriptive technique, focusing on sixth-grade elementary school students. Participants were selected based on the teacher's recommendations, specifically targeting students with strong communication skills to comprehensively examine their errors in dealing with contextual problems and their creative thinking skills. The research utilized tests and interviews as instruments for data collection, incorporating methodologies such as testing, interviewing, and triangulation. The results indicate a significant deficiency in students' innovative thinking skills, rendering them unable to solve problems effectively, which leads to an inability to meet the four criteria of creative thinking. Based on the Action-Process-Objects-Scheme (APOS) theory, the identified errors in students' approaches to contextual mathematical problems can be categorized into four types: (1) interpretive errors, (2) errors in conceptual understanding, (3) procedural errors, and (4) computational or technical errors. The insight gained from this study can inform the design of integer learning activities, helping minimize contextual problem-solving mistakes that require creative thinking skills. Consequently, further research is essential to develop a mathematical learning model that can enhance students' mathematical creative thinking abilities.

Keywords: Contextual problems; mathematical creative thinking skills; error identification

1. INTRODUCTION

Creative thinking is essential in the twenty-first century, particularly in the field of education (Cooper, 2021; Smith, 2022; Rahayuningsih et al., 2021). As one of the objectives of mathematics education, creative thinking can assist students in understanding their surroundings (Puspitasari et al., 2019; Yayuk et al., 2020). Furthermore, creative thinking plays a role in achieving meaningful learning (Ammaralikit & Chattiwat, 2020; Junaedi et al., 2021). As a result, teachers must foster creative thinking in classroom learning activities. Thinking creatively in mathematics is a key component for students in addressing mathematical difficulties, as it allows them to consider new facts and ideas while solving mathematical problems (Ndiung et al., 2021; Puspitasari et al., 2019). The ability to think creatively in mathematics can also be described as a cognitive function that refers to the capacity to develop mathematical ideas and concepts (Nwoke, 2021; Yayuk et al., 2020). Furthermore, the ability to think creatively in mathematics is one of the features of higher-order thinking, allowing students to generate new ideas from difficult problems (Ali et al., 2021; Junaedi et al., 2021). As a result, students must be able to think creatively in mathematics.

Many experts have presented indicators of creative thinking skills. A person with strong creative thinking abilities must meet four criteria: fluency, flexibility, originality, and elaboration (Jumadi et al., 2020; Rahayuningsih et al., 2021). Fluency is the ability to generate many types of ideas to solve problems. Flexibility refers to the capacity to provide multiple solutions to a situation. Originality is the ability to articulate original thoughts that have not previously been considered. Elaboration refers to the ability to develop ideas or thoughts and explain problems in detail. Therefore, these are the indicators of creative thinking ability in this study, according to this explanation.

Contextual problem-solving in mathematics can provide students with various ideas based on real-life experiences (Hawa et al., 2019; Nugroho et al., 2020). In addition, students will be able to solve contextual mathematical problems by correctly applying mathematical procedures or processes (Fonteles Furtado et al., 2019; Hunukumbure et al., 2021). On the other hand, students continue to make errors when dealing with contextual challenges related to creative thinking questions (Haghverdi & Wiest, 2016; Soneira, 2022). As a result, teachers should investigate student errors in order to incorporate appropriate classroom learning strategies.

Errors are a significant component of conceptual knowledge and are necessary in mathematics teaching (Barkai, 2021; Hu et al., 2022; Jones et al., 2020). As a result, teachers need to be able to identify student errors through effective error analysis (Faizah et al., 2022; Peltier & Peltier, 2020). Therefore, students are encouraged to complete the activities assigned by the teacher (Kenney et al., 2020; Santia et al., 2019). Students commonly make interpretive errors, conceptual errors, procedural errors, and computational errors (calculations) (Haghverdi & Wiest, 2016; Kenney et al., 2020; Khalid & Embong, 2019; Peltier & Peltier, 2020). For example, when students turn variables into numbers, they make interpretation errors when translating or concluding a problem statement (Kshetree et al., 2021). This is usually tied to the number object (40). The conceptual error indicates a student's failure to comprehend a concept in the problem at hand and a failure to assess the connection in a situation (Ammaralikit & Chattiwat, 2020; Köğce, 2022). Procedural errors occur when students fail to modify an algorithm despite understanding the principles (Ammaralikit & Chattiwat, 2020; Lien et al., 2021). Finally, computational errors are connected to calculation mistakes made by students (Al-Jarf, 2022; Emara et al., 2021). These errors were caused by a variety of factors, including students' low disposition toward mathematics, a poor teaching framework, insufficient teaching ability, students' perception of complex mathematics material, students' limited understanding of mathematics, and a lack of understanding in students' higher-order thinking capacity (Kshetree et al., 2021; Prayitno et al., 2022). As a result, assessing students' mental processes when solving mathematical assignments is vital.

The Action-Process-Object-Schema (APOS) theory can be used to investigate students' mental processes when answering contextual challenges related to creative thinking questions. The APOS theory is divided into four stages: action, process, object, and schema (Arnawa et al., 2021). In APOS theory, the action phase is carried out by an individual employing mathematical concepts in conjunction with a specific algorithm, directed by external stimuli during the action phase (Arnawa et al., 2021; Bintoro et al., 2021; Moon, 2019). The process phase of APOS theory includes repetitive actions and reflection, which help shift from relying on external signals to relying on internal cues (Arnawa et al., 2021; Boz-Yaman & Yiğit Koyunkaya, 2019; Tatira, 2021). The object phase of APOS theory focuses on recognizing that specific processes and transformations of action are regarded as a single entity, allowing for explicit shifts (Van Melle & Ferreira, 2022). Finally, the schema phase is a collection of predetermined ideas about actions, processes, objects, and schemas that are combined to build a mathematical structure for solving mathematical problems (Arnawa et al., 2021; Moru, 2020). APOS theory investigates what occurs in a person's mind when learning a mathematical concept and the successes and failures encountered during mathematical activities.

APOS theory provides a structured cognitive development pathway that supports creative thinking skills in mathematics. For creative thinking to be effective, students often need to develop high-level schemas (the final APOS stage). Incomplete progression through the APOS stages can limit creative thinking to less flexible or shallow approaches, potentially leading to errors. Creative thinking in mathematics can lead to errors when students generate novel solutions without a complete conceptual understanding. Creative ideas in mathematics need to be based on well-formed schemas; otherwise, students may design flawed approaches due to over-reliance on intuition or incomplete processing. Errors often highlight gaps in APOS development, especially when students fail to transition smoothly between stages (e.g., from process to object). This framework can explain why some errors occur even in students who are adept at generating creative solutions but lack schema understanding.

Numerous studies have been conducted on error analysis. Research by Didiş Kabar and Erbaş (2021) shows that students make mistakes in the four presented model problems. According to Polya, research by Sukoriyanto et al. (2016) reveals that students continue to make errors when tackling permutation and combination problems. Sari et al. (2018) state that the most common inaccuracy in representational abilities is problem-solving using arithmetic symbols. Research by Khalid and Embong (2019) indicates that errors arising when completing common problems involving integer operations are misconceptions. Ozrecberoglu et al. (2022) found that student performance in answering non-routine math tasks is low due to the frequent occurrence of errors. Finally, Jones et al. (2020) found that students had difficulties solving problems involving fractions.

According to previous research findings, academics have yet to examine the types of errors students make when answering contextual problems related to mathematical creative thinking using APOS theory. This gap in the literature encouraged the researchers to conduct a study to uncover and identify errors made by elementary school students when solving contextual problems that require creative thinking skills, utilizing APOS theory. By applying APOS theory, this study aims to identify students' errors in solving contextual problems related to creative thinking topics. The researchers chose the APOS theory because it can describe students' mental processes in constructing mathematical concepts. Furthermore, this initial identification is critical for shaping students' creative thinking skills, allowing for the development of relevant learning models based on the study's findings.

2. METHODS

2.1 Research design

The exploratory descriptive approach is used in this study's qualitative investigation. This approach aims to collect verbal data from students' responses when they complete a written test on contextual mathematical problems. In addition, open-ended questions were used in interviews to confirm the research subjects' responses. The issues addressed in this study include students' difficulties in answering contextual mathematical problems related to creative thinking skills using the APOS theory (Action-Process-Object-Schema).

2.2 Research subject

The participants in this study were all sixth-grade students from a state elementary school in Cirebon Regency. Since not all students were selected as participants, a purposive sampling technique was used to choose the research subjects. Fifty students had studied integer material. Within the allotted time, students were required to solve four contextual mathematical problems that assessed their creative thinking skills. Based on the indicators of creative thinking, all response papers were collected and analyzed. Students who performed exceptionally well were not selected as subjects. On the other hand, students who made errors while solving contextual problems, including those involving numerical material, were considered research subjects. The research subjects were chosen based on the teacher's recommendation, specifically targeting students with good communication skills to facilitate the examination and identification of errors in handling contextual problems related to creative thinking skills. Two students were selected for interviews based on the teacher's recommendation.

2.3 Research instrument

The test and interviews used as research instruments have been construct-validated by two mathematics education experts. The primary purpose of these tests is to identify various errors made by students. The test comprises four contextual questions, specifically designed based on indicators of students' creative thinking abilities. These indicators are based on the four characteristics of creative thinking according to Kshetree et al. (2021): fluency, flexibility, originality, and elaboration. Interviews are conducted to gather additional information from students' written response sheets. These interviews are unstructured, meaning that the researchers do not prepare specific questions in advance for the research subjects. Instead, students are expected to explain their responses during the interview. Interview questions are based on students' answers on the test sheets. Finally, the researchers confirm the test answers with the interviewed students.

2.4 Data collection

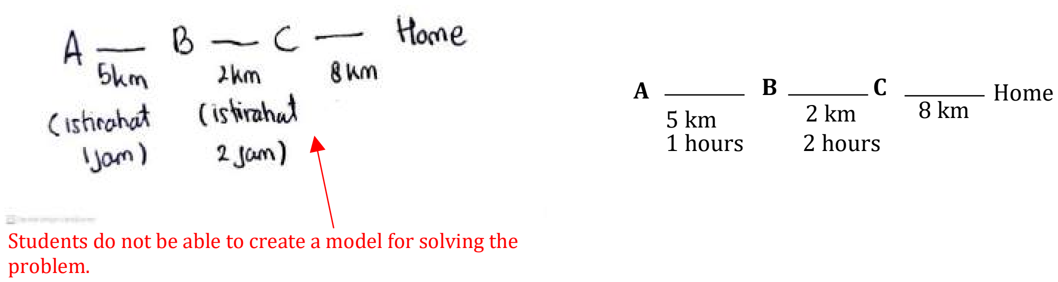
Data were collected from 40 students who completed a test consisting of four essay-style questions addressing contextual challenges related to mathematical creative thinking skills. Each student was given 40 minutes to complete the test and submit their answer sheet. The researchers reviewed the responses, focusing on identifying common errors made by students. The researchers then collaborated with the class teacher to select six students with strong communication skills for interviews. After selecting the research subjects, interviews were conducted to further corroborate the students' written responses. Interviews lasted 45 to 60 minutes, and all of them were recorded. The APOS theory was used to conduct interviews for this study to gain a deeper understanding of the error students made when tackling challenges involving mathematical creativity in context. The researchers then independently assessed the outcomes of the student interviews. After selecting the research subjects, the researchers conducted interviews to further explore and clarify the students' written responses. Each interview, lasting between 45 and 60 minutes, was fully recorded. Using the APOS theory as a framework, the interviews aimed to gain deeper insights into the specific error students made when approaching contextual challenges in mathematical creativity. The researchers then independently reviewed and analyzed the interview results. The next step involved data triangulation, achieved by comparing the results of the written test on contextual mathematical problems related to creative thinking skills with the interview insights gathered from both the researchers and students. Based on these triangulated results, the researchers derived their final findings.

2.5 Data analysis

Data analysis began with validated transcripts of interviews, student work results, and field notes, using triangulation to ensure accuracy. An open, inductive thematic approach was employed for coding, mapping transcripts into categories based on the APOS framework. Initial codes were arranged alongside the text to facilitate analysis and were continuously refined to accurately represent participants' voices. Qualitative data coding requires diverse strategies depending on the intended analysis. After reviewing the research questions, further analytical coding was conducted, addressing the research questions through APOS framework themes in a comparative and contrasting manner to obtain multi-perspective analytical dimensions. The coded transcripts were carefully reviewed to ensure that statements and quotes accurately represented the analysis. All final coding decisions were guided by the research questions and the researchers' understanding of the data at hand.

3. RESULTS AND DISCUSSION

According to the Fluency indicator, Figure 1 shows the findings from the contextual problem-solving test of students' critical thinking skills. Figure 1(a) depicts students' responses in Indonesian, and Figure 1(b) depicts students' responses in English. The test results demonstrated that students could not meet the Fluency indicator when answering contextual mathematical problems, as they could not provide various solutions. This occurred because students did not comprehend how to solve the problems, leading to mistakes. It was likely due to students' inability to understand the questions posed in these tasks. As a result, interviews were conducted to identify students' errors in solving contextual problems related to the Fluency indicator using the APOS theory.

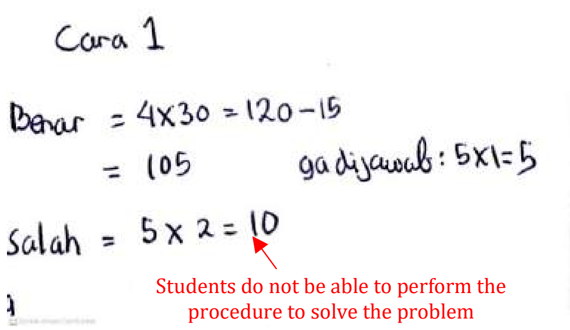


(a) **(b)**

Figure 1: Students' answers on the Fluency indicator in Indonesian (a) and in English (b)

The results of the interviews revealed that students made an interpretive error. It was shown that students did not write down what they knew or what was requested in the response. Furthermore, students drew incorrect route diagrams based on the problems in the questions. Although students could convert daily language into mathematical language, they did not understand the meaning of the questions.

Figure 2 shows the results of the contextual problem-solving test of students' creative thinking skills, measured by the Flexibility indicator. Figure 2(a) depicts students' responses in Indonesian, while Figure 2(b) depicts students' responses in English. The test findings demonstrate that students did not meet the Flexibility indicator for solving contextual mathematical problems, as they were unable to propose various solutions or approaches to the topic at hand. Furthermore, they could not present more than one approach or procedure for working on questions. This was likely due to students' inability to understand the questions raised in answering these issues, causing them to make mistakes. As a result, interviews were conducted to identify student errors in solving contextual problems using the APOS theory.



(a)

Rule 1
True = 4 x 30 = 120-15 =105
Wrong = 5 x 2 = 10

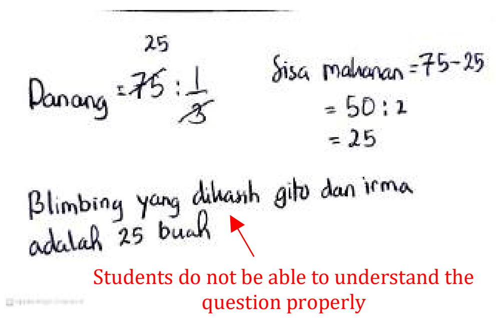
Not Answer = 5 x 1 = 5

(b)

Figure 2: Students' answers on the Flexibility indicators in Indonesian (a) and in English (b)

The interviews revealed that students made an interpretive error. It was shown that students did not write down what they knew or what was requested in the response. They could convert daily language into mathematical language, but they did not understand the significance of the questions. Students also made conceptual errors, as evidenced by a student applying the incorrect operating formula for integers. Furthermore, students made incorrect choices for the numbers to be operated on in the problem. Students also made procedural errors because they could not fully explain their answers, as well as computational errors. All of these errors were demonstrated in their responses to the problem.

Figure 3 illustrates the outcomes of the contextual problem-solving test of students' creative thinking skills, as measured by the Originality indicator. Figure 3(a) depicts students' responses in Indonesian, whereas Figure 3(b) depicts students' responses in English. The test findings demonstrate that students were unable to meet the Originality indicator when solving contextual mathematical problems because they could not convey fresh concepts that had not been previously considered. This was due to students' inability to propose original ideas and their failure to understand the questions when attempting to solve these problems. Using the APOS theory, interviews were conducted to identify student errors in solving contextual problems related to questions on the Originality indicator.



(a)

Danang = 75 : 1/3

Food left = 75 – 25
= 50 : 2
= 25

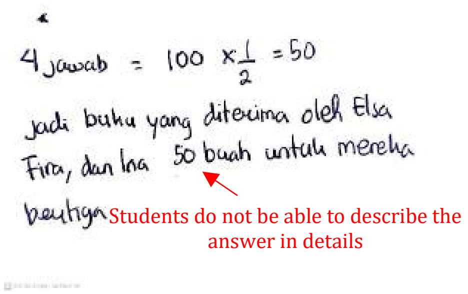
Startfruits given to Gito and Irma are 25.

(b)

Figure 3: Students' answers on the Originality indicator in Indonesian (a) and in English (b)

The results of the interviews revealed that students made errors in their understanding. They did not write down what they knew or what was requested in the response. Students could convert language into mathematical language, but they did not understand the meaning of the questions. Students also misunderstood the concepts. This was demonstrated by their incorrect use of formulas for fractional and integer arithmetic operations. Furthermore, students made incorrect choices for the numbers to be operated on in the problem. They also made procedural errors, as they could not fully explain the answers they obtained, and computational errors as well. Finally, it was shown that students provided incorrect final answers.

Figure 4 shows the results of the contextual problem-solving exam on students' creative thinking skills, as measured by the Elaboration indicator. Figure 4(a) presents students' responses in Indonesian, while Figure 4(b) shows their responses in English. The exam results indicated that students did not meet the Elaboration indicator when answering contextual mathematical problems because they were unable to develop ideas or explain the problems they had solved in detail. This was due to students' failure to describe their answers in detail, which led to mistakes. As a result, interviews need to be conducted using the APOS theory to identify student errors in solving contextual problems related to the Elaboration indicator.



Answer: 100 x 1/2

= 50

The books received by Elsa, Fira, and Lea approximately 50 books for all of them.

(a) **(b)**

Figure 4: Students' answers on the Elaboration indicator in Indonesian (a) and in English (b)

The interviews revealed that students made errors in their understanding. It was evident that students did not write down what they knew or what was requested in the response. Although students could convert everyday language into mathematical language, they did not fully grasp the significance of the questions. Students also made conceptual errors, as evidenced by their incorrect application of the operating formula for integers. Furthermore, students made incorrect choices for the numbers to be operated on in the problem. Additionally, students made procedural errors because they could not fully explain the answers they obtained, and they also made computational errors.

Students with low mathematical creative thinking abilities were chosen as research subjects. This is because the students could not answer the four questions presented in contextual situations using the four indicators of creative thinking abilities. Students' inability to attain indicators of creative thinking skills in contextual mathematical problems was driven by a lack of familiarity with these types of questions (Ilhan & Akin, 2022; Kolar & Hodnik, 2021). In addition, students were accustomed to challenges that did not necessitate the use of creative thinking skills. As a result, students must become acquainted with contextual difficulties that necessitate applying creative thinking skills (Rafiee & Abbasian-Naghneh, 2020; Yustina et al., 2022).

To handle contextual difficulties, students' creative thinking skills need to be developed. One approach is to employ a learning model that requires students to actively participate in their learning in class. Material delivery must also focus on outcomes, and problems must provide students with challenges related to contextual problems. This is consistent with research by Balakrishnan (2022), which suggests that one strategy to promote creative thinking skills in elementary school students is to use teaching strategies that require students to be active in classroom learning and familiarize them with addressing complex challenges connected to learning. Furthermore, teachers must provide immediate supportive feedback to students, allowing them to actively find their answers so that students do not struggle to solve contextual problems (Kim et al., 2022).

In sixth-grade elementary school, two students with low creative thinking skills made mistakes when answering contextual mathematical problems. Students' common errors in solving contextual problems requiring creative thinking abilities can be divided into four categories: interpretation errors, conceptual errors, procedural errors, and computational/technical errors. Students' interpretation errors occur when they fail to understand the topic or problem in the given context. They are unable to grasp the significance of the questions posed to them. Based on the four questions provided, students could not write down what was known and what was asked in the question, leading them to misinterpret the meaning.

In question one, the student incorrectly described the sketch of the route image based on the difficulty of the problem. The student created a route using only straight lines, although the question stated that the path should return to the starting position because Budi returns to the origin. The student was also incorrect in their findings in response to the inquiry. They made errors in responding correctly to the presented contextual difficulties based on the four questions. Additionally, the students did not fully comprehend the questions presented. This was due to their inability to define or comprehend sketch drawings in a specific topic (Özdemir & Dede, 2022).

Students made conceptual errors, such as incorrectly applying the formula for arithmetic operations with mixed integers. In question two, the students performed arithmetic operations on integers without considering which operation takes precedence between addition, subtraction, multiplication, and division, which led to incorrect results. The students also misunderstood the division process of numbers in question two. In response to question two, the students answered $75 \div \frac{1}{3}$. In this question, the students crossed out the numbers 75 and 3, showing that they had a wrong understanding of division and multiplication operations. The correct concept is $75 \div \frac{1}{3} = 75 \times 3$. Additionally, students chose the incorrect number to operate on in the problem. This was because they did not fully comprehend what was being asked in the problem, causing numbers that did not need to be operated on to become operational (Joung & Kim, 2022).

Based on the four questions, students experienced errors in choosing the numbers to operate on. This was due to their failure to read the questions carefully, which led to misunderstandings of what the questions actually signified. Students' understanding of mathematical concepts remains low. The result is supported by Karakuş et al. (2022), who indicate that students' conceptual comprehension is poor when answering specific mathematical problems. As a result, students make conceptual errors. The finding is supported by a study by Tooher and Johnson (2020), which found that students struggle to grasp particular mathematical topics if they do not understand the concepts relevant to the studied issues. Students will make mistakes when answering problems, particularly contextual ones. Conceptual errors can also develop as a result of prior knowledge. This is consistent with the findings of a study by Jarrah et al. (2022), which found that students' conceptual errors are also caused by prior mathematical learning. For example, students are unable to comprehend integer concepts because they merely memorize integer formulas without understanding the concept or how to apply them. As a result, students struggle to gain a correct and comprehensive understanding of the concept (Barbieri & Booth, 2020).

Students made procedural errors, including failing to explain the steps on the answer sheet adequately. In question one, students only mentioned the outcome and were unable to explain the methods used to obtain the answer. Then, in questions two and three, students could explain the steps involved, but only partially, as their final answers were incorrect. The students could not clarify their answers to question four because they misinterpreted the significance of the question. Furthermore, students were incorrect in concluding the results of the given problem. This was demonstrated in question five, where students assumed that the books delivered to Elsa, Fira, and Ina were all the same, totaling 50 books. The problem fails to indicate that the book distribution among Elsa, Fira, and Ina was the same. As a result, students did not understand the significance of the problem, and their conclusions were incorrect. Students were also incorrect in executing integer operations when solving problems, even though they had reached the correct conclusions. Therefore, students need to apply all the principles required to answer the problem to avoid errors in determining the outcome (Hu et al., 2022). Students must be able to present valid mathematical reasoning, draw conclusions, and develop generalizations in order to solve specific mathematical problems (Köğce, 2022).

Students' technical or computational errors occurred during the calculation procedure. For example, this can be observed in the process of multiplying integers in problem number two. The student carried out the operation $6 \times (-1) = -5$. The conclusions of these calculations were incorrect, resulting in incorrect final answers to the problems. This finding aligns with the study by Khalid and Embong (2019), which found that most students had broad misconceptions regarding integer operations, such as the multiplication of positive and negative integers. Errors in dividing integers by fractions occurred because students were less attentive while performing operations. As a result, a technical error occurred. For example, in question three, students completed the operation $75 \div \frac{1}{3} = 25$. The outcomes of these calculations were inaccurate, causing students to conclude the final answer to the presented questions incorrectly. According to the study, the most common mistakes students make in the operation of dividing integers are those who are negligent in using the methods provided in the problems (Üzel, 2018). As a result, students must have strong fundamental mathematical problem-solving abilities to solve contextual mathematical problems (Sternberg et al., 2021). This is essential to ensure that students' mistakes do not reoccur.

According to the findings, sixth-grade students were still in the action stage of the APOS theory. This occurs because students lack an APOS conceptual structure, which causes them to make errors when faced with contextual mathematical problems. For example, students have trouble implementing integer operations due to a lack of conceptual structure related to the process, object, and schema stages (Kshetree et al., 2021). This demonstrates that students cannot manage the application of theorems and formulas required for specific mathematical problems. Based on the APOS theory analysis, students have difficulties understanding the concept of operations on numbers. This is because, at the previous level, students could not understand the concept of operations on integers, which caused them to make errors in solving the problems presented. Students only memorize formulas, so they struggle when learning about the concept of operations on integers.

In addition, students lack experience understanding integer operations, do not fully understand the concept of integer operations, and have minimal prior knowledge of integer operations from the previous level. As a result, teachers must have an effective strategy to identify student errors. One technique for reducing student errors in handling contextual problems is to hold open discussions that focus on efforts to overcome student errors during the learning process (Ilhan & Akin, 2022).

Assessing and analyzing students' errors in completing contextual problems on creative thinking skills is considered an essential tool for learning (Rahayuningsih et al., 2021). Furthermore, it is indicated that to overcome cognitive obstacles in solving difficulties presented in mathematics learning, students must have a positive mindset and engage in optimal thinking activities that activate prior knowledge and experience in solving specific problems. Since students in different courses differ in their capacities for creative thought, the understanding of individual students should be considered while designing a teacher's thinking activity (Jumadi et al., 2020).

These findings suggest that teachers should appropriately prepare students on both the procedural and conceptual aspects of mathematics. Both features are critical in comprehending mathematical material (Barbieri & Booth, 2020). Identifying students' errors in addressing contextual mathematical problems and their ability to think creatively about integer operations has helped teachers recognize students' shortcomings. This will assist teachers in preparing classroom activities and addressing errors that occur. Students' errors are caused by a lack of creative thinking skills when tackling contextual mathematical problems. According to Tooher and Johnson (2020), a student with low skills in creative thinking will make mistakes in solving the problem.

Therefore, students' ability to think creatively needs to be developed so that similar errors do not occur again. After improving their creative thinking skills, students will be able to develop their own formulas or principles for solving mathematical problems. According to the research, strengthening mathematical creative thinking skills would allow students to pay attention to all components required to solve mathematical problems, enabling them to discover formulas or rules on their own (Foster, 2021).

4. CONCLUSION

It can be concluded that the students selected for the study did not meet the four creative thinking indicators of fluency, flexibility, originality, and elaboration. This incapacity was caused by errors made by students when tackling contextual problem-solving tasks that required creative thinking skills. According to the APOS theory, student errors include: (1) Misinterpretation errors: incorrectly converting the questions into mathematical language/symbols and misinterpreting the given questions; (2) Conceptual errors: students misused formulas when working with fractions and integers. Furthermore, students made incorrect choices for the numbers that were operated on in the problem; (3) Procedural errors: students improperly concluded the question. This occurred because students failed to pay attention to what was asked in the question and were incorrect in carrying out the processes needed to solve the problem, as they were unable to explain the solutions they had received; (4) Technical/computational errors: students made mistakes in computations involving integer operations, and their final answers to the questions they worked on were incorrect.

Future studies should focus on the development of new learning models capable of improving mathematical creative thinking skills. This is significant because research shows that students with strong creative thinking skills adapt quickly to new problems. On the other hand, students who lack creative thinking skills will struggle to solve problems. Future research should explore how students think while tackling contextual problems in mathematics. Identifying students' cognitive processes will help them gain a better understanding, as they approach problem-solving in specific ways. When teachers understand their students' thought processes, they can quickly identify students' problems solving skills. As a result, the teacher can adjust the learning approach for future lessons.

REFERENCES

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature review: Mathematical creative thinking ability and students' self-regulated learning to use an open-ended approach. *Malikussaleh Journal of Mathematics Learning, 4*(1), 52–61.

Al-Jarf, R. (2022). Student-interpreters' foreign proper noun pronunciation errors in English-Arabic and Arabic-English media discourse interpreting. *International Journal of Translation and Interpretation Studies, 2*(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11

Ammaralikit, A., & Chattiwat, W. (2020). Effects of the business reading model on Thai learners' reading and creative thinking abilities. *English Language Teaching, 13*(5), 191–208. https://doi.org/10.5539/elt.v13n5p191

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? *International Journal of Instruction, 14*(3), 175–186. https://doi.org/10.29333/iji.2021.14310a

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: A study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education, 32*(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on display: Incorrect examples refine equation solving and algebraic feature knowledge. *Applied Cognitive Psychology, 34*(4), 862–878. https://doi.org/10.1002/acp.3663

Barkai, R. (2021). Using cases as a means to discuss errors in mathematics teacher education. *Education Sciences, 11*(10), Article 575. https://doi.org/10.3390/educsci11100575

Bintoro, H. S., Walid, & Mulyono. (2021). The spatial thinking process of field-independent students based on the action-process-object-schema theory. *European Journal of Educational Research, 10*(4), 1807–1823.

Boz-Yaman, B., & Yiğit Koyunkaya, M. (2019). Examination of pre-service mathematics teachers' mental constructions of function transformation. *Acta Didactica Napocensia, 12*(1), 33–56. https://doi.org/10.24193/adn.12.1.3

Cooper, A. A. (2021). Incorporating critical and creative thinking in a transitions course. *Primus, 31*(9), 995–1006. https://doi.org/10.1080/10511970.2020.1805659

Didiş Kabar, M. G., & Erbaş, A. K. (2021). Pre-service secondary mathematics teachers' anticipation and identification of students' thinking in the context of modelling problems. *International Journal of Mathematical Education in Science and Technology, 52*(2), 208–236. https://doi.org/10.1080/0020739X.2019.1670368

Emara, M., Hutchins, N. M., Grover, S., Snyder, C., & Biswas, G. (2021). Examining student regulation of collaborative, computational, problem-solving processes in open-ended learning environments. *Journal of Learning Analytics, 8*(1), 49–74. https://doi.org/10.18608/JLA.2021.7230

Faizah, S., Nusantara, T., Sudirman, & Rahardi, R. (2022). Constructing students' thinking process through assimilation and accommodation framework. *Mathematics Teaching-Research Journal, 14*(1), 253–269.

Fonteles Furtado, P. G., Hirashima, T., Hayashi, Y., & Maeda, K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. *Research and Practice in Technology Enhanced Learning, 14*(1), Article 2. https://doi.org/10.1186/s41039-019-0096-1

Foster, M. K. (2021). Design thinking: A creative approach to problem solving. *Management Teaching Review, 6*(2), 123–140. https://doi.org/10.1177/2379298119871468

Haghverdi, M., & Wiest, L. R. (2016). The effect of contextual and conceptual rewording on mathematical problem-solving performance. *The Mathematics Educator, 25*(1), 56–73.

Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient approach to teach literary sociology. *International Journal of Instruction, 12*(1), 283–298. https://doi.org/10.29333/iji.2019.12119a

Hu, Q., Son, J. W., & Hodge, L. (2022). Algebra teachers' interpretation and responses to student errors in solving quadratic equations. *International Journal of Science and Mathematics Education, 20*(3), 637–657. https://doi.org/10.1007/s10763-021-10166-1

Hunukumbure, A. D., Horner, P. J., Fox, J., & Thakerar, V. (2021). An online discussion between students and teachers: A way forward for meaningful teacher feedback? *BMC Medical Education, 21*(1), Article 289. https://doi.org/10.1186/s12909-021-02730-8

Ilhan, A., & Akin, M. F. (2022). Analysis of contextual problem solutions, mathematical sentences, and misconceptions of pre-service mathematics teachers. *International Electronic Journal of Mathematics Education, 17*(1), Article em0666. https://doi.org/10.29333/iejme/11470

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(6), Article em2115. https://doi.org/10.29333/ejmste/12070

Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. *School Science and Mathematics, 120*(4), 232–243. https://doi.org/10.1111/ssm.12402

Joung, E., & Kim, Y. R. (2022). Identifying preservice teachers' concept-based and procedure-based error patterns in multiplying and dividing decimals. *International Journal of Education in Mathematics, Science and Technology, 10*(3), 549–567. https://doi.org/10.46328/ijemst.2227

Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE), 9*(2), 415–420. https://doi.org/10.11591/ijere.v9i2.20531

Junaedi, Y., Wahyudin, & Juandi, D. (2021). Mathematical creative thinking ability of junior high school students' on polyhedron. *Journal of Physics: Conference Series, 1806*(1), 36–45. https://doi.org/10.1088/1742-6596/1806/1/012069

Karakuş, D., Özkaya, M., & Konyalıoğlu, A. C. (2022). GeoGebra in the correction and understanding of errors regarding the concept of asymptote. *Shanlax International Journal of Education, 10*(2), 67–79. https://doi.org/10.34293/education.v10i2.4400

Kenney, R., An, T., Kim, S. H., Uhan, N. A., Yi, J. S., & Shamsul, A. (2020). Linear programming models: Identifying common errors in engineering students' work with complex word problems. *International Journal of Science and Mathematics Education, 18*(4), 635–655. https://doi.org/10.1007/s10763-019-09980-5

Khalid, M., & Embong, Z. (2019). Sources and possible causes of errors and misconceptions in operations of integers. *International Electronic Journal of Mathematics Education, 15*(2), Article em0568. https://doi.org/10.29333/iejme/6265

Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving. *International Journal of Science and Mathematics Education, 20*(2), 215–236. https://doi.org/10.1007/s10763-020-10145-y

Köğce, D. (2022). Examination of mathematical errors and mistakes in calculus course. *Educational Policy Analysis and Strategic Research, 17*(1), 295–311. https://doi.org/10.29329/epasr.2022.248.15

Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. *European Journal of Educational Research, 10*(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467

Kshetree, M. P., Acharya, B. R., Khanal, B., & Panthi, R. K. (2021). Eighth grade students' misconceptions and errors in mathematics learning in Nepal. *European Journal of Educational Research, 10*(4), 1907–1918.

Lien, N. T. N., Khuyen, N. T. T., Tho, N. T., Hoa, N. N., Hanh, N. T., Tho, C. C., Hai, T. D., & Van Bien, N. (2021). Teachers' feelings of safeness in school-family-community partnerships: Motivations for sustainable development in moral education. *International Journal of Evaluation and Research in Education, 10*(1), 97–107. https://doi.org/10.11591/ijere.v10i1.20798

Moon, K. (2019). Preservice teachers' understanding of two-variable inequalities: APOS theory. In S. Otten, A. G. Candela, Z. de Araujo, C. Haines, & C. Munter (Eds.), *Proceedings of the Forty-first Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 686–694). University of Missouri.

Moru, E. K. (2020). An APOS analysis of university students' understanding of derivatives: A Lesotho case study. *African Journal of Research in Mathematics, Science and Technology Education, 24*(2), 279–292. https://doi.org/10.1080/18117295.2020.1821500

Ndiung, S., Sariyasa, J., Jehadus, E., & Apsar, R. A. (2021). The effect of Treffinger creative learning model with the use of RME principles on creative thinking skills and mathematics learning outcomes. *International Journal of Instruction, 14*(2), 873–888.

Nugroho, A. A., Nizarudin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students' creative thinking in the use of representations in solving mathematical problems based on cognitive style. *Journal of Research and Advances in Mathematics Education, 5*(2), 202–217. https://doi.org/10.23917/jramathedu.v5i2.9983

Nwoke, B. L. (2021). Enhancing primary school pupils' mathematics creative ability through activity based learning approach. *Malikussaleh Journal of Mathematics Learning (MJML), 4*(2), 70–76.

Özdemir, E., & Dede, E. (2022). Investigation of the ways prospective mathematics teachers respond to students' errors: An example of the equal sign. *International Online Journal of Education and Teaching (IOJET), 9*(2), 723–739.

Ozrecberoglu, N., Aydın, S., & Aydın, O. (2022). Students' skills in solving non-routine mathematical problems. *Education Quarterly Reviews, 5*(2), 446–461. https://doi.org/10.31014/aior.1993.05.02.504

Peltier, C., & Peltier, T. K. (2020). Mining instruction from student mistakes: Conducting an error analysis for mathematical problem solving. *Beyond Behavior, 29*(3), 141–151. https://doi.org/10.1177/1074295620903050

Prayitno, A. T., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2022). Identification of graph thinking in solving mathematical problems naturally. *Participatory Educational Research, 9*(2), 118–135. https://doi.org/10.17275/per.22.32.9.2

Puspitasari, L., In, A., & Syaifuddin, M. (2019). Analysis of students' creative thinking in solving arithmetic problems. *International Electronic Journal of Mathematics Education, 14*(1), 49–60.

Rafiee, M., & Abbasian-Naghneh, S. (2020). Willingness to write (WTW): Development of a model in EFL writing classrooms. *Cogent Education, 7*(1), Article 1847710. https://doi.org/10.1080/2331186X.2020.1847710

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. *Participatory Educational Research, 8*(3), 285–299. https://doi.org/10.17275/per.21.66.8.3

Santia, I., Purwanto, Sutawidjadja, A., Sudirman, & Subanji. (2019). Exploring mathematical representations in solving ill-structured problems: The case of quadratic function. *Journal on Mathematics Education, 10*(3), 365–378. https://doi.org/10.22342/jme.10.3.7600.365-378

Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with react strategy in solving the problems of mathematical representation ability. *Journal on Mathematics Education, 9*(1), 121–128. https://doi.org/10.22342/jme.9.1.4378.121-128

Smith, J. E. (2022). Creative self-efficacy: An essential transition skill for students with learning disabilities. *Intervention in School and Clinic, 57*(4), 256–261. https://doi.org/10.1177/10534512211024938

Soneira, C. (2022). The use of representations when solving algebra word problems and the sources of solution errors. *International Journal of Science and Mathematics Education, 20*(5), 1037–1056. https://doi.org/10.1007/s10763-021-10181-2

Sternberg, R. J., Glaveanu, V., Karami, S., Kaufman, J. C., Phillipson, S. N., & Preiss, D. D. (2021). Meta-intelligence: Understanding, control, and interactivity between creative, analytical, practical, and wisdom-based approaches in problem solving. *Journal of Intelligence, 9*(2), Article 19. https://doi.org/10.3390/jintelligence9020019

Sukoriyanto, S., Nusantara, T., Subanji, S., & Chandra, T. D. (2016). Students' errors in solving the permutation and combination problems based on problem-solving steps of Polya. *International Education Studies, 9*(2), Article 11. https://doi.org/10.5539/ies.v9n2p11

Tatira, B. (2021). Mathematics education students' understanding of binomial series expansion based on the APOS theory. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(12), Article em2035. https://doi.org/10.29333/EJMSTE/11287

Tooher, H., & Johnson, P. (2020). The role of analogies and anchors in addressing students' misconceptions with algebraic equations. *Issues in Educational Research, 30*(2), 756–781.

Üzel, D. (2018). Investigation of misconceptions and errors about division operation in fractions. *Universal Journal of Educational Research, 6*(11), 2656–2662. https://doi.org/10.13189/ujer.2018.061131

Van Melle, J., & Ferreira, M. (2022). Developing students' intercultural sensitivity at the home campus: An innovative approach using the theory of the creative action methodology pedagogy. *Teaching and Learning Inquiry, 10*, 1–23. https://doi.org/10.20343/TEACHLEARNINQU.10.12

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research, 9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yustina, Mahadi, I., Ariska, D., Arnentis, & Darmadi. (2022). The effect of e-learning based on the problem-based learning model on students' creative thinking skills during the COVID-19 pandemic. *International Journal of Instruction, 15*(2), 329–348. https://doi.org/10.29333/iji.2022.15219a

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Mathematical creative thinking skills: Using APOS theory to identify student errors in solving contextual problems

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Abstract

Individuals with strong creative thinking abilities are particularly adept at effectively addressing mathematical contextual problems. However, students often need more vital creative thinking skills in the classroom, frequently due to errors they make themselves. This study aims to identify students' specific

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References

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature review: Mathematical creative thinking ability and students' self-regulated learning to use an open-ended approach. Malikussaleh Journal of Mathematics Learning, 4(1), 52–61.

Al-Jarf, R. (2022). Student-interpreters' foreign proper noun pronunciation errors in English-Arabic and Arabic-English media discourse interpreting. International Journal of Translation and Interpretation Studies, 2(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11

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References

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature review: Mathematical creative thinking ability and students' self-regulated learning to use an open-ended approach. Malikussaleh Journal of Mathematics Learning, 4(1), 52–61.

Al-Jarf, R. (2022). Student-interpreters' foreign proper noun pronunciation errors in English-Arabic and Arabic-English media discourse interpreting. International Journal of Translation and Interpretation Studies, 2(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11

Ammaralikit, A., & Chattiwat, W. (2020). Effects of the business reading model on Thai learners' reading and creative thinking abilities. English Language Teaching, 13(5), 191–208. https://doi.org/10.5539/elt.v13n5p191

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? International Journal of Instruction, 14(3), 175–186. https://doi.org/10.29333/iji.2021.14310a

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: A study on creative skills and motivation to think creatively. International Journal of Technology and Design Education, 32(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on display: Incorrect examples refine equation solving and algebraic feature knowledge. Applied Cognitive Psychology, 34(4), 862–878. https://doi.org/10.1002/acp.3663

Barkai, R. (2021). Using cases as a means to discuss errors in mathematics teacher education. Education Sciences, 11(10), Article 575. https://doi.org/10.3390/educsci11100575

Bintoro, H. S., Walid, & Mulyono. (2021). The spatial thinking process of field-independent students based on the action-process-object-schema theory. European Journal of Educational Research, 10(4), 1807–1823.

Boz-Yaman, B., & Yiğit Koyunkaya, M. (2019). Examination of pre-service mathematics teachers' mental constructions of function transformation. Acta Didactica Napocensia, 12(1), 33–56. https://doi.org/10.24193/adn.12.1.3

Cooper, A. A. (2021). Incorporating critical and creative thinking in a transitions course. Primus, 31(9), 995–1006. https://doi.org/10.1080/10511970.2020.1809659

Didiş Kabar, M. G., & Erbaş, A. K. (2021). Pre-service secondary mathematics teachers' anticipation and identification of students' thinking in the context of modelling problems. International Journal of Mathematical Education in Science and Technology, 52(2), 208–236. https://doi.org/10.1080/0020739X.2019.1670368

Emara, M., Hutchins, N. M., Grover, S., Snyder, C., & Biswas, G. (2021). Examining student regulation of collaborative, computational, problem-solving processes in open-ended learning environments. Journal of Learning Analytics, 8(1), 49–74. https://doi.org/10.18608/jla.2021.7230

Fatah, S., Nusantara, T., Sudirman, & Rahardi, R. (2022). Constructing students' thinking process through assimilation and accommodation framework. Mathematics Teaching-Research Journal, 14(1), 253–269.

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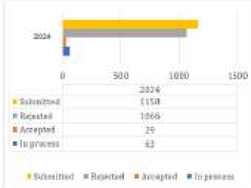

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IN 17,134 SG 3,888
US 12,655 GB 3,830
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FLAG counter
Counter installed June 1, 2018

Fonteles Furtado, P. G., Hirashima, T., Hayashi, Y., & Maeda, K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. Research and Practice in Technology Enhanced Learning, 14(1), Article 2. https://doi.org/10.1186/s41039-019-0096-1

Foster, M. K. (2021). Design thinking: A creative approach to problem solving. Management Teaching Review, 6(2), 123–140. https://doi.org/10.1177/2379298119871468

Haghverdi, M., & Wiest, L. R. (2016). The effect of contextual and conceptual rewording on mathematical problem-solving performance. The Mathematics Educator, 25(1), 56–73.

Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient
Haghverdi, M., & Wiest, L. R. (2016). The effect of contextual and conceptual rewording on mathematical problem-solving performance. The Mathematics Educator, 25(1), 56–73.
Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient approach to teach literary sociology. International Journal of Instruction, 12(1), 283–298. https://doi.org/10.29333/iji.2019.12119a

Hu, Q., Son, J. W., & Hodge, L. (2022). Algebra teachers' interpretation and responses to student errors in solving quadratic equations. International Journal of Science and Mathematics Education, 20(3), 637–657. https://doi.org/10.1007/s10763-021-10166-1

Hunukumbure, A. D., Horner, P. J., Fox, J., & Thakerar, V. (2021). An online discussion between students and teachers: A way forward for meaningful teacher feedback? BMC Medical Education, 21(1), Article 289. https://doi.org/10.1186/s12909-021-02730-8

Ilhan, A., & Akin, M. F. (2022). Analysis of contextual problem solutions, mathematical sentences, and misconceptions of pre-service mathematics teachers. International Electronic Journal of Mathematics Education, 17(1), Article em0666. https://doi.org/10.29333/iejme/11470

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. Eurasia Journal of Mathematics, Science and Technology Education, 18(6), Article em2115. https://doi.org/10.29333/ejmste/12070

Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. School Science and Mathematics, 120(4), 232–243. https://doi.org/10.1111/ssm.12402

Joung, E., & Kim, Y. R. (2022). Identifying preservice teachers' concept-based and procedure-based error patterns in multiplying and dividing decimals. International Journal of Education in Mathematics, Science and Technology, 10(3), 549–567. https://doi.org/10.46328/ijemst.2227

Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics
Ilhan, A., & Akin, M. F. (2022). Analysis of contextual problem solutions, mathematical sentences, and misconceptions of pre-service mathematics teachers. International Electronic Journal of Mathematics Education, 17(1), Article em0666. https://doi.org/10.29333/iejme/11470

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. Eurasia Journal of Mathematics, Science and Technology Education, 18(6), Article em2115. https://doi.org/10.29333/ejmste/12070

Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. School Science and Mathematics, 120(4), 232–243. https://doi.org/10.1111/ssm.12402

Joung, E., & Kim, Y. R. (2022). Identifying preservice teachers' concept-based and procedure-based error patterns in multiplying and dividing decimals. International Journal of Education in Mathematics, Science and Technology, 10(3), 549–567. https://doi.org/10.46328/ijemst.2227
Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. International Journal of Evaluation and Research in Education (IJERE), 9(2), 415–420. https://doi.org/10.11591/ijere.v9i2.20531

Junaedi, Y., Wahyudin, & Juandi, D. (2021). Mathematical creative thinking ability of junior high school students' on polyhedron. Journal of Physics: Conference Series, 1806(1), 36–45. https://doi.org/10.1088/1742-6596/1806/1/012069

Karakuş, D., Özkaya, M., & Konyalıoğlu, A. C. (2022). GeoGebra in the correction and understanding of errors regarding the concept of asymptote. Shanlax International Journal of Education, 10(2), 67–79. https://doi.org/10.34293/education.v10i2.4400

Kenney, R., An, T., Kim, S. H., Uhan, N. A., Yi, J. S., & Shamsul, A. (2020). Linear programming models: Identifying common errors in engineering students' work with complex word problems. International Journal of Science and Mathematics Education, 18(4), 635–655. https://doi.org/10.1007/s10763-019-09980-5

Khalid, M., & Embong, Z. (2019). Sources and possible causes of errors and misconceptions in operations of integers. International Electronic Journal of Mathematics Education, 15(2), Article em0568. https://doi.org/10.29333/iejme/6265

Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving. International Journal of Science and Mathematics Education, 20(2), 215–236. https://doi.org/10.1007/s10763-020-10145-y

Koğce, D. (2022). Examination of mathematical errors and mistakes in calculus course. Educational Policy Analysis and Strategic Research, 17(1), 295–311. https://doi.org/10.29329/epasr.2022.248.15

Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. European Journal of Educational Research, 10(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467

Kshetree, M. P., Acharya, B. R., Khanal, B., & Panthi, R. K. (2021). Eighth grade students' misconceptions and errors in mathematics learning in Nepal. European Journal of Educational Research, 10(4), 1907–1918.

Lien, N. T. N., Khuyen, N. T. T., Tho, N. T., Hoa, N. N., Hanh, N. T., Tho, C. C., Hai, T. D., & Van Bien, N. (2021). Teachers' feelings of safeness in school-family-community partnerships: Motivations for sustainable development in moral education. International Journal of Evaluation and Research in Education, 10(1), 97–107. https://doi.org/10.11591/ijere.v10i1.20798

Moon, K. (2019). Preservice teachers' understanding of two-variable inequalities: APOS theory. In S. Otten, A. G. Candela, Z. de Araujo, C. Haines, & C. Munter (Eds.), Proceedings of the Forty-first Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (pp. 686–694). University of Missouri.

Moru, E. K. (2020). An APOS analysis of university students' understanding of derivatives: A Lesotho case study. African Journal of Research in Mathematics, Science and Technology Education, 24(2), 279–292. https://doi.org/10.1080/18117295.2020.1821500

Ndiung, S., Sariyasa, J., Jehadus, E., & Apsar, R. A. (2021). The effect of Treffinger creative learning model with the use of RME principles on creative thinking skills and mathematics learning outcomes. International Journal of Instruction, 14(2), 873–888.

Nugroho, A. A., Nizarudin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students' creative thinking in the use of representations in solving mathematical problems based on cognitive style. Journal of Research and Advances in Mathematics Education, 5(2), 202–217. https://doi.org/10.23917/jramathedu.v5i2.9983

Nwoke, B. L. (2021). Enhancing primary school pupils' mathematics creative ability through activity based learning approach. Malikussaleh Journal of Mathematics Learning (MJML), 4(2), 70–76.

Özdemir, E., & Dede, E. (2022). Investigation of the ways prospective mathematics teachers respond to students' errors: An example of the equal sign. International Online Journal of Education and Teaching (IOJET), 9(2), 723–739.

Ozrecberoglu, N., Aydin, S., & Aydin, O. (2022). Students' skills in solving non-routine mathematical problems. Education Quarterly Reviews, 5(2), 446–461. https://doi.org/10.31014/aior.1993.05.02.504

Peltier, C., & Peltier, T. K. (2020). Mining instruction from student mistakes: Conducting an error analysis for mathematical problem solving. Beyond Behavior, 29(3), 141–151. https://doi.org/10.1177/1074295620903060

Prayitno, A. T., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2022). Identification of graph thinking in solving mathematical problems naturally. Participatory Educational Research, 9(2), 118–135. https://doi.org/10.17275/per.22.32.9.2

Puspitasari, L., In, A., & Syaifuddin, M. (2019). Analysis of students' creative thinking in solving arithmetic problems. International Electronic Journal of Mathematics Education, 14(1), 49–60.

Rafiee, M., & Abbasian-Naghneh, S. (2020). Willingness to write (WTW): Development of a model in EFL writing classrooms. Cogent Education, 7(1), Article 1847710. https://doi.org/10.1080/2331186X.2020.1847710

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. Participatory Educational Research, 8(3), 285–299. https://doi.org/10.17275/per.21.66.8.3

Santia, I., Purwanto, Sutawidjadja, A., Sudirman, & Subanji. (2019). Exploring mathematical representations in solving ill-structured problems: The case of quadratic function. Journal on Mathematics Education, 10(3), 365–378. https://doi.org/10.22342/jme.10.3.7600.365-378

Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with react strategy in solving the problems of mathematical representation ability. Journal on Mathematics Education, 9(1), 121–128. https://doi.org/10.22342/jme.9.1.4378.121-128

Smith, J. E. (2022). Creative self-efficacy: An essential transition skill for students with learning disabilities. Intervention in School and Clinic, 57(4), 256–261. https://doi.org/10.1177/10534512211024938

Soneira, C. (2022). The use of representations when solving algebra word problems and the sources of solution errors. International Journal of Science and Mathematics Education, 20(5), 1037–1056. https://doi.org/10.1007/s10763-021-10181-2

Sternberg, R. J., Glaveanu, V., Karami, S., Kaufman, J. C., Phillipson, S. N., & Preiss, D. D. (2021). Meta-intelligence: Understanding, control, and interactivity between creative, analytical, practical, and wisdom-based approaches in problem solving. Journal of Intelligence, 9(2), Article 19. https://doi.org/10.3390/jintelligence9020019

Sukoriyanto, S., Nusantara, T., Subanji, S., & Chandra, T. D. (2016). Students' errors in solving the permutation and combination problems based on problem-solving steps of Polya. International Education Studies, 9(2), Article 11. https://doi.org/10.5539/ies.v9n2p11

Tatira, B. (2021). Mathematics education students' understanding of binomial series expansion based on the APOS theory. Eurasia Journal of Mathematics, Science and Technology Education, 17(12), Article em2035. https://doi.org/10.29333/ejmste/11287

Tocher, H., & Johnson, P. (2020). The role of analogies and anchors in addressing students' misconceptions with algebraic equations. Issues in Educational Research, 30(2), 756–781.

Uzel, D. (2018). Investigation of misconceptions and errors about division operation in fractions. Universal Journal of Educational Research, 6(11), 2656–2662. https://doi.org/10.13189/ujer.2018.061131

Van Melle, J., & Ferreira, M. (2022). Developing students' intercultural sensitivity at the home campus: An innovative approach using the theory of the creative action methodology pedagogy. Teaching and Learning Inquiry, 10, 1–23. https://doi.org/10.20343/TEACHLEARNINQU.10.12

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. European Journal of Educational Research, 9(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yustina, Mahadi, I., Ariska, D., Arnentis, & Darmadi. (2022). The effect of e-learning based on the problem-based learning model on students' creative thinking skills during the COVID-19 pandemic. International Journal of Instruction, 15(2), 329–348. https://doi.org/10.29333/iji.2022.15219a

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MATHEMATICAL CREATIVE THINKING SKILLS: USING APOS THEORY TO IDENTIFY STUDENT ERRORS IN SOLVING CONTEXTUAL PROBLEMS

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ABSTRACT

Individuals with strong creative thinking abilities are particularly adept at effectively addressing mathematical contextual problems. However, students often need more vital creative thinking skills in the classroom, frequently due to errors they make themselves. This study aims to identify students' specific errors when solving contextual problems related to integer operations. This research adopts a qualitative approach, using an exploratory and descriptive technique, focusing on sixth-grade elementary school students. Participants were selected based on the teacher's recommendations, specifically targeting students with strong communication skills to comprehensively examine their errors in dealing with contextual problems and their creative thinking skills. The research utilized tests and interviews as instruments for data collection, incorporating methodologies such as testing, interviewing, and triangulation. The results indicate a significant deficiency in students' innovative thinking skills, rendering them unable to solve problems effectively, which leads to an inability to meet the four criteria of creative thinking. Based on the Action-Process-Objects-Scheme (APOS) theory, the identified errors in students' approaches to contextual mathematical problems can be categorized into four types: (1) interpretive errors, (2) errors in conceptual understanding, (3) procedural errors, and (4) computational or technical errors. The insight gained from this study can inform the design of integer learning activities, helping minimize contextual problem-solving mistakes that require creative thinking skills. Consequently, further research is essential to develop a mathematical learning model that can enhance students' mathematical creative thinking abilities.

Keywords: Contextual problems; mathematical creative thinking skills; error identification

1. INTRODUCTION

Creative thinking is essential in the twenty-first century, particularly in the field of education (Cooper, 2021; Smith, 2022; Rahayuningsih et al., 2021). As one of the objectives of mathematics education, creative thinking can assist students in understanding their surroundings (Puspitasari et al., 2019; Yayuk et al., 2020). Furthermore, creative thinking plays a role in achieving meaningful learning (Ammaralikit & Chattiwat, 2020; Junaedi et al., 2021). As a result, teachers must foster creative thinking in classroom learning activities. Thinking creatively in mathematics is a key component for students in addressing mathematical difficulties, as it allows them to consider new facts and ideas while solving mathematical problems (Ndiung et al., 2021; Puspitasari et al., 2019). The ability to think creatively in mathematics can also be described as a cognitive function that refers to the capacity to develop mathematical ideas and concepts (Nwoke, 2021; Yayuk et al., 2020). Furthermore, the ability to think creatively in mathematics is one of the features of higher-order thinking, allowing students to generate new ideas from difficult problems (Ali et al., 2021; Junaedi et al., 2021). As a result, students must be able to think creatively in mathematics.

Many experts have presented indicators of creative thinking skills. A person with strong creative thinking abilities must meet four criteria: fluency, flexibility, originality, and elaboration (Jumadi et al., 2020; Rahayuningsih et al., 2021). Fluency is the ability to generate many types of ideas to solve problems. Flexibility refers to the capacity to provide multiple solutions to a situation. Originality is the ability to articulate original thoughts that have not previously been considered. Elaboration refers to the ability to develop ideas or thoughts and explain problems in detail. Therefore, these are the indicators of creative thinking ability in this study, according to this explanation.

Contextual problem-solving in mathematics can provide students with various ideas based on real-life experiences (Hawa et al., 2019; Nugroho et al., 2020). In addition, students will be able to solve contextual mathematical problems by correctly applying mathematical procedures or processes (Fonteles Furtado et al., 2019; Hunukumbure et al., 2021). On the other hand, students continue to make errors when dealing with contextual challenges related to creative thinking questions (Haghverdi & Wiest, 2016; Soneira, 2022). As a result, teachers should investigate student errors in order to incorporate appropriate classroom learning strategies.

Errors are a significant component of conceptual knowledge and are necessary in mathematics teaching (Barkai, 2021; Hu et al., 2022; Jones et al., 2020). As a result, teachers need to be able to identify student errors through effective error analysis (Faizah et al., 2022; Peltier & Peltier, 2020). Therefore, students are encouraged to complete the activities assigned by the teacher (Kenney et al., 2020; Santia et al., 2019). Students commonly make interpretive errors, conceptual errors, procedural errors, and computational errors (calculations) (Haghverdi & Wiest, 2016; Kenney et al., 2020; Khalid & Embong, 2019; Peltier & Peltier, 2020). For example, when students turn variables into numbers, they make interpretation errors when translating or concluding a problem statement (Kshetree et al., 2021). This is usually tied to the number object (40). The conceptual error indicates a student's failure to comprehend a concept in the problem at hand and a failure to assess the connection in a situation (Ammaralikit & Chattiwat, 2020; Köğce, 2022). Procedural errors occur when students fail to modify an algorithm despite understanding the principles (Ammaralikit & Chattiwat, 2020; Lien et al., 2021). Finally, computational errors are connected to calculation mistakes made by students (Al-Jarf, 2022; Emara et al., 2021). These errors were caused by a variety of factors, including students' low disposition toward mathematics, a poor teaching framework, insufficient teaching ability, students' perception of complex mathematics material, students' limited understanding of mathematics, and a lack of understanding in students' higher-order thinking capacity (Kshetree et al., 2021; Prayitno et al., 2022). As a result, assessing students' mental processes when solving mathematical assignments is vital.

The Action-Process-Object-Schema (APOS) theory can be used to investigate students' mental processes when answering contextual challenges related to creative thinking questions. The APOS theory is divided into four stages: action, process, object, and schema (Arnawa et al., 2021). In APOS theory, the action phase is carried out by an individual employing mathematical concepts in conjunction with a specific algorithm, directed by external stimuli during the action phase (Arnawa et al., 2021; Bintoro et al., 2021; Moon, 2019). The process phase of APOS theory includes repetitive actions and reflection, which help shift from relying on external signals to relying on internal cues (Arnawa et al., 2021; Boz-Yaman & Yiğit Koyunkaya, 2019; Tatira, 2021). The object phase of APOS theory focuses on recognizing that specific processes and transformations of action are regarded as a single entity, allowing for explicit shifts (Van Melle & Ferreira, 2022). Finally, the schema phase is a collection of predetermined ideas about actions, processes, objects, and schemas that are combined to build a mathematical structure for solving mathematical problems (Arnawa et al., 2021; Moru, 2020). APOS theory investigates what occurs in a person's mind when learning a mathematical concept and the successes and failures encountered during mathematical activities.

APOS theory provides a structured cognitive development pathway that supports creative thinking skills in mathematics. For creative thinking to be effective, students often need to develop high-level schemas (the final APOS stage). Incomplete progression through the APOS stages can limit creative thinking to less flexible or shallow approaches, potentially leading to errors. Creative thinking in mathematics can lead to errors when students generate novel solutions without a complete conceptual understanding. Creative ideas in mathematics need to be based on well-formed schemas; otherwise, students may design flawed approaches due to over-reliance on intuition or incomplete processing. Errors often highlight gaps in APOS development, especially when students fail to transition smoothly between stages (e.g., from process to object). This framework can explain why some errors occur even in students who are adept at generating creative solutions but lack schema understanding.

Numerous studies have been conducted on error analysis. Research by Didiş Kabar and Erbaş (2021) shows that students make mistakes in the four presented model problems. According to Polya, research by Sukoriyanto et al. (2016) reveals that students continue to make errors when tackling permutation and combination problems. Sari et al. (2018) state that the most common inaccuracy in representational abilities is problem-solving using arithmetic symbols. Research by Khalid and Embong (2019) indicates that errors arising when completing common problems involving integer operations are misconceptions. Ozrecberoglu et al. (2022) found that student performance in answering non-routine math tasks is low due to the frequent occurrence of errors. Finally, Jones et al. (2020) found that students had difficulties solving problems involving fractions.

According to previous research findings, academics have yet to examine the types of errors students make when answering contextual problems related to mathematical creative thinking using APOS theory. This gap in the literature encouraged the researchers to conduct a study to uncover and identify errors made by elementary school students when solving contextual problems that require creative thinking skills, utilizing APOS theory. By applying APOS theory, this study aims to identify students' errors in solving contextual problems related to creative thinking topics. The researchers chose the APOS theory because it can describe students' mental processes in constructing mathematical concepts. Furthermore, this initial identification is critical for shaping students' creative thinking skills, allowing for the development of relevant learning models based on the study's findings.

2. METHODS

2.1 Research design

The exploratory descriptive approach is used in this study's qualitative investigation. This approach aims to collect verbal data from students' responses when they complete a written test on contextual mathematical problems. In addition, open-ended questions were used in interviews to confirm the research subjects' responses. The issues addressed in this study include students' difficulties in answering contextual mathematical problems related to creative thinking skills using the APOS theory (Action-Process-Object-Schema).

2.2 Research subject

The participants in this study were all sixth-grade students from a state elementary school in Cirebon Regency. Since not all students were selected as participants, a purposive sampling technique was used to choose the research subjects. Fifty students had studied integer material. Within the allotted time, students were required to solve four contextual mathematical problems that assessed their creative thinking skills. Based on the indicators of creative thinking, all response papers were collected and analyzed. Students who performed exceptionally well were not selected as subjects. On the other hand, students who made errors while solving contextual problems, including those involving numerical material, were considered research subjects. The research subjects were chosen based on the teacher's recommendation, specifically targeting students with good communication skills to facilitate the examination and identification of errors in handling contextual problems related to creative thinking skills. Two students were selected for interviews based on the teacher's recommendation.

2.3 Research instrument

The test and interviews used as research instruments have been construct-validated by two mathematics education experts. The primary purpose of these tests is to identify various errors made by students. The test comprises four contextual questions, specifically designed based on indicators of students' creative thinking abilities. These indicators are based on the four characteristics of creative thinking according to Kshetree et al. (2021): fluency, flexibility, originality, and elaboration. Interviews are conducted to gather additional information from students' written response sheets. These interviews are unstructured, meaning that the researchers do not prepare specific questions in advance for the research subjects. Instead, students are expected to explain their responses during the interview. Interview questions are based on students' answers on the test sheets. Finally, the researchers confirm the test answers with the interviewed students.

2.4 Data collection

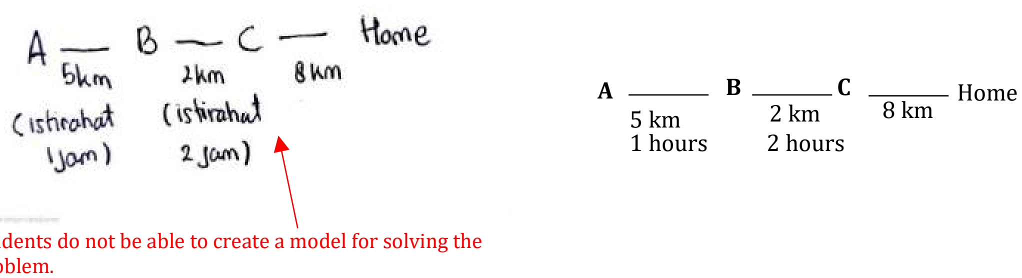
Data were collected from 40 students who completed a test consisting of four essay-style questions addressing contextual challenges related to mathematical creative thinking skills. Each student was given 40 minutes to complete the test and submit their answer sheet. The researchers reviewed the responses, focusing on identifying common errors made by students. The researchers then collaborated with the class teacher to select six students with strong communication skills for interviews. After selecting the research subjects, interviews were conducted to further corroborate the students' written responses. Interviews lasted 45 to 60 minutes, and all of them were recorded. The APOS theory was used to conduct interviews for this study to gain a deeper understanding of the error students made when tackling challenges involving mathematical creativity in context. The researchers then independently assessed the outcomes of the student interviews. After selecting the research subjects, the researchers conducted interviews to further explore and clarify the students' written responses. Each interview, lasting between 45 and 60 minutes, was fully recorded. Using the APOS theory as a framework, the interviews aimed to gain deeper insights into the specific error students made when approaching contextual challenges in mathematical creativity. The researchers then independently reviewed and analyzed the interview results. The next step involved data triangulation, achieved by comparing the results of the written test on contextual mathematical problems related to creative thinking skills with the interview insights gathered from both the researchers and students. Based on these triangulated results, the researchers derived their final findings.

2.5 Data analysis

Data analysis began with validated transcripts of interviews, student work results, and field notes, using triangulation to ensure accuracy. An open, inductive thematic approach was employed for coding, mapping transcripts into categories based on the APOS framework. Initial codes were arranged alongside the text to facilitate analysis and were continuously refined to accurately represent participants' voices. Qualitative data coding requires diverse strategies depending on the intended analysis. After reviewing the research questions, further analytical coding was conducted, addressing the research questions through APOS framework themes in a comparative and contrasting manner to obtain multi-perspective analytical dimensions. The coded transcripts were carefully reviewed to ensure that statements and quotes accurately represented the analysis. All final coding decisions were guided by the research questions and the researchers' understanding of the data at hand.

3. RESULTS AND DISCUSSION

According to the Fluency indicator, Figure 1 shows the findings from the contextual problem-solving test of students' critical thinking skills. Figure 1(a) depicts students' responses in Indonesian, and Figure 1(b) depicts students' responses in English. The test results demonstrated that students could not meet the Fluency indicator when answering contextual mathematical problems, as they could not provide various solutions. This occurred because students did not comprehend how to solve the problems, leading to mistakes. It was likely due to students' inability to understand the questions posed in these tasks. As a result, interviews were conducted to identify students' errors in solving contextual problems related to the Fluency indicator using the APOS theory.

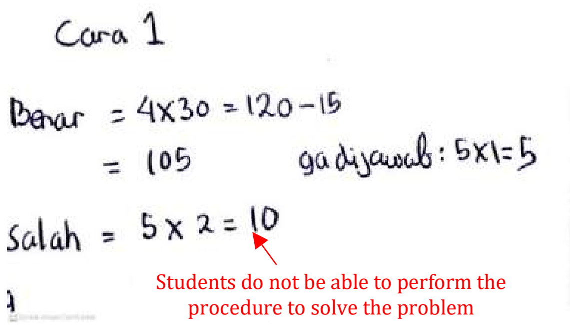


(a) **(b)**

Figure 1: Students' answers on the Fluency indicator in Indonesian (a) and in English (b)

The results of the interviews revealed that students made an interpretive error. It was shown that students did not write down what they knew or what was requested in the response. Furthermore, students drew incorrect route diagrams based on the problems in the questions. Although students could convert daily language into mathematical language, they did not understand the meaning of the questions.

Figure 2 shows the results of the contextual problem-solving test of students' creative thinking skills, measured by the Flexibility indicator. Figure 2(a) depicts students' responses in Indonesian, while Figure 2(b) depicts students' responses in English. The test findings demonstrate that students did not meet the Flexibility indicator for solving contextual mathematical problems, as they were unable to propose various solutions or approaches to the topic at hand. Furthermore, they could not present more than one approach or procedure for working on questions. This was likely due to students' inability to understand the questions raised in answering these issues, causing them to make mistakes. As a result, interviews were conducted to identify student errors in solving contextual problems using the APOS theory.



(a)

Rule 1
True = 4 x 30 = 120-15 =105
Wrong = 5 x 2 = 10

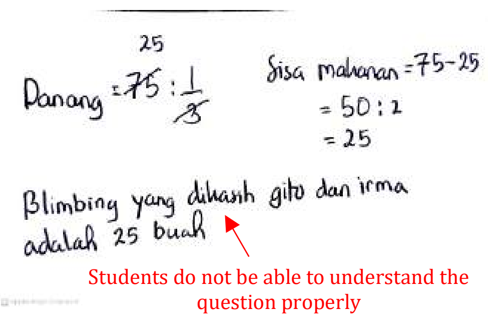
Not Answer = 5 x 1 = 5

(b)

Figure 2: Students' answers on the Flexibility indicators in Indonesian (a) and in English (b)

The interviews revealed that students made an interpretive error. It was shown that students did not write down what they knew or what was requested in the response. They could convert daily language into mathematical language, but they did not understand the significance of the questions. Students also made conceptual errors, as evidenced by a student applying the incorrect operating formula for integers. Furthermore, students made incorrect choices for the numbers to be operated on in the problem. Students also made procedural errors because they could not fully explain their answers, as well as computational errors. All of these errors were demonstrated in their responses to the problem.

Figure 3 illustrates the outcomes of the contextual problem-solving test of students' creative thinking skills, as measured by the Originality indicator. Figure 3(a) depicts students' responses in Indonesian, whereas Figure 3(b) depicts students' responses in English. The test findings demonstrate that students were unable to meet the Originality indicator when solving contextual mathematical problems because they could not convey fresh concepts that had not been previously considered. This was due to students' inability to propose original ideas and their failure to understand the questions when attempting to solve these problems. Using the APOS theory, interviews were conducted to identify student errors in solving contextual problems related to questions on the Originality indicator.



(a)

Danang = 75 : 1/3

Food left = 75 – 25
= 50 : 2
= 25

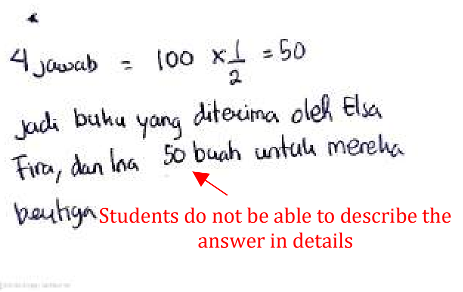
Startfruits given to Gito and Irma are 25.

(b)

Figure 3: Students' answers on the Originality indicator in Indonesian (a) and in English (b)

The results of the interviews revealed that students made errors in their understanding. They did not write down what they knew or what was requested in the response. Students could convert language into mathematical language, but they did not understand the meaning of the questions. Students also misunderstood the concepts. This was demonstrated by their incorrect use of formulas for fractional and integer arithmetic operations. Furthermore, students made incorrect choices for the numbers to be operated on in the problem. They also made procedural errors, as they could not fully explain the answers they obtained, and computational errors as well. Finally, it was shown that students provided incorrect final answers.

Figure 4 shows the results of the contextual problem-solving exam on students' creative thinking skills, as measured by the Elaboration indicator. Figure 4(a) presents students' responses in Indonesian, while Figure 4(b) shows their responses in English. The exam results indicated that students did not meet the Elaboration indicator when answering contextual mathematical problems because they were unable to develop ideas or explain the problems they had solved in detail. This was due to students' failure to describe their answers in detail, which led to mistakes. As a result, interviews need to be conducted using the APOS theory to identify student errors in solving contextual problems related to the Elaboration indicator.



(a)

Answer: 100 x 1/2

= 50

The books received by Elsa, Fira, and Lea approximately 50 books for all of them.

(b)

Figure 4: Students' answers on the Elaboration indicator in Indonesian (a) and in English (b)

The interviews revealed that students made errors in their understanding. It was evident that students did not write down what they knew or what was requested in the response. Although students could convert everyday language into mathematical language, they did not fully grasp the significance of the questions. Students also made conceptual errors, as evidenced by their incorrect application of the operating formula for integers. Furthermore, students made incorrect choices for the numbers to be operated on in the problem. Additionally, students made procedural errors because they could not fully explain the answers they obtained, and they also made computational errors.

Students with low mathematical creative thinking abilities were chosen as research subjects. This is because the students could not answer the four questions presented in contextual situations using the four indicators of creative thinking abilities. Students' inability to attain indicators of creative thinking skills in contextual mathematical problems was driven by a lack of familiarity with these types of questions (Ilhan & Akin, 2022; Kolar & Hodnik, 2021). In addition, students were accustomed to challenges that did not necessitate the use of creative thinking skills. As a result, students must become acquainted with contextual difficulties that necessitate applying creative thinking skills (Rafiee & Abbasian-Naghneh, 2020; Yustina et al., 2022).

To handle contextual difficulties, students' creative thinking skills need to be developed. One approach is to employ a learning model that requires students to actively participate in their learning in class. Material delivery must also focus on outcomes, and problems must provide students with challenges related to contextual problems. This is consistent with research by Balakrishnan (2022), which suggests that one strategy to promote creative thinking skills in elementary school students is to use teaching strategies that require students to be active in classroom learning and familiarize them with addressing complex challenges connected to learning. Furthermore, teachers must provide immediate supportive feedback to students, allowing them to actively find their answers so that students do not struggle to solve contextual problems (Kim et al., 2022).

In sixth-grade elementary school, two students with low creative thinking skills made mistakes when answering contextual mathematical problems. Students' common errors in solving contextual problems requiring creative thinking abilities can be divided into four categories: interpretation errors, conceptual errors, procedural errors, and computational/technical errors. Students' interpretation errors occur when they fail to understand the topic or problem in the given context. They are unable to grasp the significance of the questions posed to them. Based on the four questions provided, students could not write down what was known and what was asked in the question, leading them to misinterpret the meaning.

In question one, the student incorrectly described the sketch of the route image based on the difficulty of the problem. The student created a route using only straight lines, although the question stated that the path should return to the starting position because Budi returns to the origin. The student was also incorrect in their findings in response to the inquiry. They made errors in responding correctly to the presented contextual difficulties based on the four questions. Additionally, the students did not fully comprehend the questions presented. This was due to their inability to define or comprehend sketch drawings in a specific topic (Özdemir & Dede, 2022).

Students made conceptual errors, such as incorrectly applying the formula for arithmetic operations with mixed integers. In question two, the students performed arithmetic operations on integers without considering which operation takes precedence between addition, subtraction, multiplication, and division, which led to incorrect results. The students also misunderstood the division process of numbers in question two. In response to question two, the students answered $75 \div \frac{1}{3}$. In this question, the students crossed out the numbers 75 and 3, showing that they had a wrong understanding of division and multiplication operations. The correct concept is $75 \div \frac{1}{3} = 75 \times 3$. Additionally, students chose the incorrect number to operate on in the problem. This was because they did not fully comprehend what was being asked in the problem, causing numbers that did not need to be operated on to become operational (Joung & Kim, 2022).

Based on the four questions, students experienced errors in choosing the numbers to operate on. This was due to their failure to read the questions carefully, which led to misunderstandings of what the questions actually signified. Students' understanding of mathematical concepts remains low. The result is supported by Karakuş et al. (2022), who indicate that students' conceptual comprehension is poor when answering specific mathematical problems. As a result, students make conceptual errors. The finding is supported by a study by Tooher and Johnson (2020), which found that students struggle to grasp particular mathematical topics if they do not understand the concepts relevant to the studied issues. Students will make mistakes when answering problems, particularly contextual ones. Conceptual errors can also develop as a result of prior knowledge. This is consistent with the findings of a study by Jarrah et al. (2022), which found that students' conceptual errors are also caused by prior mathematical learning. For example, students are unable to comprehend integer concepts because they merely memorize integer formulas without understanding the concept or how to apply them. As a result, students struggle to gain a correct and comprehensive understanding of the concept (Barbieri & Booth, 2020).

Students made procedural errors, including failing to explain the steps on the answer sheet adequately. In question one, students only mentioned the outcome and were unable to explain the methods used to obtain the answer. Then, in questions two and three, students could explain the steps involved, but only partially, as their final answers were incorrect. The students could not clarify their answers to question four because they misinterpreted the significance of the question. Furthermore, students were incorrect in concluding the results of the given problem. This was demonstrated in question five, where students assumed that the books delivered to Elsa, Fira, and Ina were all the same, totaling 50 books. The problem fails to indicate that the book distribution among Elsa, Fira, and Ina was the same. As a result, students did not understand the significance of the problem, and their conclusions were incorrect. Students were also incorrect in executing integer operations when solving problems, even though they had reached the correct conclusions. Therefore, students need to apply all the principles required to answer the problem to avoid errors in determining the outcome (Hu et al., 2022). Students must be able to present valid mathematical reasoning, draw conclusions, and develop generalizations in order to solve specific mathematical problems (Köğce, 2022).

Students' technical or computational errors occurred during the calculation procedure. For example, this can be observed in the process of multiplying integers in problem number two. The student carried out the operation $6 \times (-1) = -5$. The conclusions of these calculations were incorrect, resulting in incorrect final answers to the problems. This finding aligns with the study by Khalid and Embong (2019), which found that most students had broad misconceptions regarding integer operations, such as the multiplication of positive and negative integers. Errors in dividing integers by fractions occurred because students were less attentive while performing operations. As a result, a technical error occurred. For example, in question three, students completed the operation $75 \div \frac{1}{3} = 25$. The outcomes of these calculations were inaccurate, causing students to conclude the final answer to the presented questions incorrectly. According to the study, the most common mistakes students make in the operation of dividing integers are those who are negligent in using the methods provided in the problems (Üzel, 2018). As a result, students must have strong fundamental mathematical problem-solving abilities to solve contextual mathematical problems (Sternberg et al., 2021). This is essential to ensure that students' mistakes do not reoccur.

According to the findings, sixth-grade students were still in the action stage of the APOS theory. This occurs because students lack an APOS conceptual structure, which causes them to make errors when faced with contextual mathematical problems. For example, students have trouble implementing integer operations due to a lack of conceptual structure related to the process, object, and schema stages (Kshetree et al., 2021). This demonstrates that students cannot manage the application of theorems and formulas required for specific mathematical problems. Based on the APOS theory analysis, students have difficulties understanding the concept of operations on numbers. This is because, at the previous level, students could not understand the concept of operations on integers, which caused them to make errors in solving the problems presented. Students only memorize formulas, so they struggle when learning about the concept of operations on integers.

In addition, students lack experience understanding integer operations, do not fully understand the concept of integer operations, and have minimal prior knowledge of integer operations from the previous level. As a result, teachers must have an effective strategy to identify student errors. One technique for reducing student errors in handling contextual problems is to hold open discussions that focus on efforts to overcome student errors during the learning process (Ilhan & Akin, 2022).

Assessing and analyzing students' errors in completing contextual problems on creative thinking skills is considered an essential tool for learning (Rahayuningsih et al., 2021). Furthermore, it is indicated that to overcome cognitive obstacles in solving difficulties presented in mathematics learning, students must have a positive mindset and engage in optimal thinking activities that activate prior knowledge and experience in solving specific problems. Since students in different courses differ in their capacities for creative thought, the understanding of individual students should be considered while designing a teacher's thinking activity (Jumadi et al., 2020).

These findings suggest that teachers should appropriately prepare students on both the procedural and conceptual aspects of mathematics. Both features are critical in comprehending mathematical material (Barbieri & Booth, 2020). Identifying students' errors in addressing contextual mathematical problems and their ability to think creatively about integer operations has helped teachers recognize students' shortcomings. This will assist teachers in preparing classroom activities and addressing errors that occur. Students' errors are caused by a lack of creative thinking skills when tackling contextual mathematical problems. According to Tooher and Johnson (2020), a student with low skills in creative thinking will make mistakes in solving the problem.

Therefore, students' ability to think creatively needs to be developed so that similar errors do not occur again. After improving their creative thinking skills, students will be able to develop their own formulas or principles for solving mathematical problems. According to the research, strengthening mathematical creative thinking skills would allow students to pay attention to all components required to solve mathematical problems, enabling them to discover formulas or rules on their own (Foster, 2021).

4. CONCLUSION

It can be concluded that the students selected for the study did not meet the four creative thinking indicators of fluency, flexibility, originality, and elaboration. This incapacity was caused by errors made by students when tackling contextual problem-solving tasks that required creative thinking skills. According to the APOS theory, student errors include: (1) Misinterpretation errors: incorrectly converting the questions into mathematical language/symbols and misinterpreting the given questions; (2) Conceptual errors: students misused formulas when working with fractions and integers. Furthermore, students made incorrect choices for the numbers that were operated on in the problem; (3) Procedural errors: students improperly concluded the question. This occurred because students failed to pay attention to what was asked in the question and were incorrect in carrying out the processes needed to solve the problem, as they were unable to explain the solutions they had received; (4) Technical/computational errors: students made mistakes in computations involving integer operations, and their final answers to the questions they worked on were incorrect.

Future studies should focus on the development of new learning models capable of improving mathematical creative thinking skills. This is significant because research shows that students with strong creative thinking skills adapt quickly to new problems. On the other hand, students who lack creative thinking skills will struggle to solve problems. Future research should explore how students think while tackling contextual problems in mathematics. Identifying students' cognitive processes will help them gain a better understanding, as they approach problem-solving in specific ways. When teachers understand their students' thought processes, they can quickly identify students' problems solving skills. As a result, the teacher can adjust the learning approach for future lessons.

REFERENCES

Ali, D., Mz, Z. A., & Vebrianto, R. (2021). Literature review: Mathematical creative thinking ability and students' self-regulated learning to use an open-ended approach. *Malikussaleh Journal of Mathematics Learning, 4*(1), 52–61.

Al-Jarf, R. (2022). Student-interpreters' foreign proper noun pronunciation errors in English-Arabic and Arabic-English media discourse interpreting. *International Journal of Translation and Interpretation Studies, 2*(1), 80–90. https://doi.org/10.32996/ijtis.2022.2.1.11

Ammaralikit, A., & Chattiwat, W. (2020). Effects of the business reading model on Thai learners' reading and creative thinking abilities. *English Language Teaching, 13*(5), 191–208. https://doi.org/10.5539/elt.v13n5p191

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? *International Journal of Instruction, 14*(3), 175–186. https://doi.org/10.29333/iji.2021.14310a

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: A study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education, 32*(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on display: Incorrect examples refine equation solving and algebraic feature knowledge. *Applied Cognitive Psychology, 34*(4), 862–878. https://doi.org/10.1002/acp.3663

Barkai, R. (2021). Using cases as a means to discuss errors in mathematics teacher education. *Education Sciences, 11*(10), Article 575. https://doi.org/10.3390/educsci11100575

Bintoro, H. S., Walid, & Mulyono. (2021). The spatial thinking process of field-independent students based on the action-process-object-schema theory. *European Journal of Educational Research, 10*(4), 1807–1823.

Boz-Yaman, B., & Yiğit Koyunkaya, M. (2019). Examination of pre-service mathematics teachers' mental constructions of function transformation. *Acta Didactica Napocensia, 12*(1), 33–56. https://doi.org/10.24193/adn.12.1.3

Cooper, A. A. (2021). Incorporating critical and creative thinking in a transitions course. *Primus, 31*(9), 995–1006. https://doi.org/10.1080/10511970.2020.1805659

Didiş Kabar, M. G., & Erbaş, A. K. (2021). Pre-service secondary mathematics teachers' anticipation and identification of students' thinking in the context of modelling problems. *International Journal of Mathematical Education in Science and Technology, 52*(2), 208–236. https://doi.org/10.1080/0020739X.2019.1670368

Emara, M., Hutchins, N. M., Grover, S., Snyder, C., & Biswas, G. (2021). Examining student regulation of collaborative, computational, problem-solving processes in open-ended learning environments. *Journal of Learning Analytics, 8*(1), 49–74. https://doi.org/10.18608/JLA.2021.7230

Faizah, S., Nusantara, T., Sudirman, & Rahardi, R. (2022). Constructing students' thinking process through assimilation and accommodation framework. *Mathematics Teaching-Research Journal, 14*(1), 253–269.

Fonteles Furtado, P. G., Hirashima, T., Hayashi, Y., & Maeda, K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. *Research and Practice in Technology Enhanced Learning, 14*(1), Article 2. https://doi.org/10.1186/s41039-019-0096-1

Foster, M. K. (2021). Design thinking: A creative approach to problem solving. *Management Teaching Review, 6*(2), 123–140. https://doi.org/10.1177/2379298119871468

Haghverdi, M., & Wiest, L. R. (2016). The effect of contextual and conceptual rewording on mathematical problem-solving performance. *The Mathematics Educator, 25*(1), 56–73.

Hawa, M., Andayani, Suyitno, & Wardani, N. E. (2019). The implementation of literary sociology learning model with contextual and spiritual quotient approach to teach literary sociology. *International Journal of Instruction, 12*(1), 283–298. https://doi.org/10.29333/iji.2019.12119a

Hu, Q., Son, J. W., & Hodge, L. (2022). Algebra teachers' interpretation and responses to student errors in solving quadratic equations. *International Journal of Science and Mathematics Education, 20*(3), 637–657. https://doi.org/10.1007/s10763-021-10166-1

Hunukumbure, A. D., Horner, P. J., Fox, J., & Thakerar, V. (2021). An online discussion between students and teachers: A way forward for meaningful teacher feedback? *BMC Medical Education, 21*(1), Article 289. https://doi.org/10.1186/s12909-021-02730-8

Ilhan, A., & Akin, M. F. (2022). Analysis of contextual problem solutions, mathematical sentences, and misconceptions of pre-service mathematics teachers. *International Electronic Journal of Mathematics Education, 17*(1), Article em0666. https://doi.org/10.29333/iejme/11470

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(6), Article em2115. https://doi.org/10.29333/ejmste/12070

Jones, D. L., Zientek, L. R., Sharon, V. V., & Swarthout, M. B. (2020). Solving equations with fractions: An analysis of prospective teachers' solution pathways and errors. *School Science and Mathematics, 120*(4), 232–243. https://doi.org/10.1111/ssm.12402

Joung, E., & Kim, Y. R. (2022). Identifying preservice teachers' concept-based and procedure-based error patterns in multiplying and dividing decimals. *International Journal of Education in Mathematics, Science and Technology, 10*(3), 549–567. https://doi.org/10.46328/ijemst.2227

Jumadi, J., Gummah, S., Ahzan, S., Sabda, D., & Prasetya, B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE), 9*(2), 415–420. https://doi.org/10.11591/ijere.v9i2.20531

Junaedi, Y., Wahyudin, & Juandi, D. (2021). Mathematical creative thinking ability of junior high school students' on polyhedron. *Journal of Physics: Conference Series, 1806*(1), 36–45. https://doi.org/10.1088/1742-6596/1806/1/012069

Karakuş, D., Özkaya, M., & Konyalıoğlu, A. C. (2022). GeoGebra in the correction and understanding of errors regarding the concept of asymptote. *Shanlax International Journal of Education, 10*(2), 67–79. https://doi.org/10.34293/education.v10i2.4400

Kenney, R., An, T., Kim, S. H., Uhan, N. A., Yi, J. S., & Shamsul, A. (2020). Linear programming models: Identifying common errors in engineering students' work with complex word problems. *International Journal of Science and Mathematics Education, 18*(4), 635–655. https://doi.org/10.1007/s10763-019-09980-5

Khalid, M., & Embong, Z. (2019). Sources and possible causes of errors and misconceptions in operations of integers. *International Electronic Journal of Mathematics Education, 15*(2), Article em0568. https://doi.org/10.29333/iejme/6265

Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving. *International Journal of Science and Mathematics Education, 20*(2), 215–236. https://doi.org/10.1007/s10763-020-10145-y

Köğce, D. (2022). Examination of mathematical errors and mistakes in calculus course. *Educational Policy Analysis and Strategic Research, 17*(1), 295–311. https://doi.org/10.29329/epasr.2022.248.15

Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. *European Journal of Educational Research, 10*(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467

Kshetree, M. P., Acharya, B. R., Khanal, B., & Panthi, R. K. (2021). Eighth grade students' misconceptions and errors in mathematics learning in Nepal. *European Journal of Educational Research, 10*(4), 1907–1918.

Lien, N. T. N., Khuyen, N. T. T., Tho, N. T., Hoa, N. N., Hanh, N. T., Tho, C. C., Hai, T. D., & Van Bien, N. (2021). Teachers' feelings of safeness in school-family-community partnerships: Motivations for sustainable development in moral education. *International Journal of Evaluation and Research in Education, 10*(1), 97–107. https://doi.org/10.11591/ijere.v10i1.20798

Moon, K. (2019). Preservice teachers' understanding of two-variable inequalities: APOS theory. In S. Otten, A. G. Candela, Z. de Araujo, C. Haines, & C. Munter (Eds.), *Proceedings of the Forty-first Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 686–694). University of Missouri.

Moru, E. K. (2020). An APOS analysis of university students' understanding of derivatives: A Lesotho case study. *African Journal of Research in Mathematics, Science and Technology Education, 24*(2), 279–292. https://doi.org/10.1080/18117295.2020.1821500

Ndiung, S., Sariyasa, J., Jehadus, E., & Apsar, R. A. (2021). The effect of Treffinger creative learning model with the use of RME principles on creative thinking skills and mathematics learning outcomes. *International Journal of Instruction, 14*(2), 873–888.

Nugroho, A. A., Nizarudin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students' creative thinking in the use of representations in solving mathematical problems based on cognitive style. *Journal of Research and Advances in Mathematics Education, 5*(2), 202–217. https://doi.org/10.23917/jramathedu.v5i2.9983

Nwoke, B. L. (2021). Enhancing primary school pupils' mathematics creative ability through activity based learning approach. *Malikussaleh Journal of Mathematics Learning (MJML), 4*(2), 70–76.

Özdemir, E., & Dede, E. (2022). Investigation of the ways prospective mathematics teachers respond to students' errors: An example of the equal sign. *International Online Journal of Education and Teaching (IOJET), 9*(2), 723–739.

Ozrecberoglu, N., Aydın, S., & Aydın, O. (2022). Students' skills in solving non-routine mathematical problems. *Education Quarterly Reviews, 5*(2), 446–461. https://doi.org/10.31014/aior.1993.05.02.504

Peltier, C., & Peltier, T. K. (2020). Mining instruction from student mistakes: Conducting an error analysis for mathematical problem solving. *Beyond Behavior, 29*(3), 141–151. https://doi.org/10.1177/1074295620903050

Prayitno, A. T., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2022). Identification of graph thinking in solving mathematical problems naturally. *Participatory Educational Research, 9*(2), 118–135. https://doi.org/10.17275/per.22.32.9.2

Puspitasari, L., In, A., & Syaifuddin, M. (2019). Analysis of students' creative thinking in solving arithmetic problems. *International Electronic Journal of Mathematics Education, 14*(1), 49–60.

Rafiee, M., & Abbasian-Naghneh, S. (2020). Willingness to write (WTW): Development of a model in EFL writing classrooms. *Cogent Education, 7*(1), Article 1847710. https://doi.org/10.1080/2331186X.2020.1847710

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. *Participatory Educational Research, 8*(3), 285–299. https://doi.org/10.17275/per.21.66.8.3

Santia, I., Purwanto, Sutawidjadja, A., Sudirman, & Subanji. (2019). Exploring mathematical representations in solving ill-structured problems: The case of quadratic function. *Journal on Mathematics Education, 10*(3), 365–378. https://doi.org/10.22342/jme.10.3.7600.365-378

Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with react strategy in solving the problems of mathematical representation ability. *Journal on Mathematics Education, 9*(1), 121–128. https://doi.org/10.22342/jme.9.1.4378.121-128

Smith, J. E. (2022). Creative self-efficacy: An essential transition skill for students with learning disabilities. *Intervention in School and Clinic, 57*(4), 256–261. https://doi.org/10.1177/10534512211024938

Soneira, C. (2022). The use of representations when solving algebra word problems and the sources of solution errors. *International Journal of Science and Mathematics Education, 20*(5), 1037–1056. https://doi.org/10.1007/s10763-021-10181-2

Sternberg, R. J., Glaveanu, V., Karami, S., Kaufman, J. C., Phillipson, S. N., & Preiss, D. D. (2021). Meta-intelligence: Understanding, control, and interactivity between creative, analytical, practical, and wisdom-based approaches in problem solving. *Journal of Intelligence, 9*(2), Article 19. https://doi.org/10.3390/jintelligence9020019

Sukoriyanto, S., Nusantara, T., Subanji, S., & Chandra, T. D. (2016). Students' errors in solving the permutation and combination problems based on problem-solving steps of Polya. *International Education Studies, 9*(2), Article 11. https://doi.org/10.5539/ies.v9n2p11

Tatira, B. (2021). Mathematics education students' understanding of binomial series expansion based on the APOS theory. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(12), Article em2035. https://doi.org/10.29333/EJMSTE/11287

Tooher, H., & Johnson, P. (2020). The role of analogies and anchors in addressing students' misconceptions with algebraic equations. *Issues in Educational Research, 30*(2), 756–781.

Üzel, D. (2018). Investigation of misconceptions and errors about division operation in fractions. *Universal Journal of Educational Research, 6*(11), 2656–2662. https://doi.org/10.13189/ujer.2018.061131

Van Melle, J., & Ferreira, M. (2022). Developing students' intercultural sensitivity at the home campus: An innovative approach using the theory of the creative action methodology pedagogy. *Teaching and Learning Inquiry, 10*, 1–23. https://doi.org/10.20343/TEACHLEARNINQU.10.12

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research, 9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yustina, Mahadi, I., Ariska, D., Arnentis, & Darmadi. (2022). The effect of e-learning based on the problem-based learning model on students' creative thinking skills during the COVID-19 pandemic. *International Journal of Instruction, 15*(2), 329–348. https://doi.org/10.29333/iji.2022.15219a