Analysis of Mathematical Creative Thinking Ability in Terms of Self-Regulated Learning in Creative Problem Solving Learning Model with Performance Assessment

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Abstract

This study aims to (1) analyze the quality of Creative Problem Solving (CPS) learning model with performance assessment on students' mathematical creative thinking abilities; (2) analyze students' mathematical creative thinking abilities in terms of Self-Regulated Learning (SRL). The research sample were class VIII A as the experimental class and class VIII B as the control class. There were 6 research subjects taken based on the level of SRL using purposive sampling technique in class VIII A of SMP Negeri 1 Tayu in 2022/2023 academic year.

The results showed that (1) CPS learning with performance assessment has the quality in improving students' mathematical creative thinking abilities; (2) subjects with high SRL were able to fulfill all indicators of mathematical creative thinking abilities namely fluency, flexibility, originality, and elaboration; subjects with medium SRL only met fluency, originality, and elaboration; subjects with low SRL only met fluency and originality.

Keywords: Mathematical Creative Thinking Abilities, Self-Regulated Learning, Creative Problem Solving, Performance Assesment

1. Introduction

Facing the challenges of the 21st century, students are required to master thinking abilities. Laar et al. (2017) classifies 21st century abilities into seven namely technical, information management, communication, collaboration, creativity, critical thinking, and problem solving. Partnership for 21st Century Skills (2008), identifies 21st century abilities including creativity and innovation, critical thinking and problem solving, communication, and collaboration. These capabilities are known as 4C. Based on this, it can be concluded that the ability to think creatively is very important for students to face the challenges of the 21st century.

The creative thinking ability of students in Indonesia can be said to be very low. This can be proven by the assessment of the International Student Assessment Program (PISA). The 2018 PISA results show that Indonesia is ranked 72 out of 78 countries with a score of 379 in mathematics (OECD, 2019). According to research by Wang et al. (2011) regarding the relationship between creative thinking and the ability to read and write shows that there is a positive relationship between the ability to think creatively and write and read.

The ability to think creatively mathematically is one of the abilities that is needed in the process of learning mathematics in the classroom. Tabach & Friedlander (2017) state that students' mathematical creative thinking abilities have an influence on students' conceptual understanding abilities during the mathematics learning process because students who have high creative thinking abilities then when solving a problem will apply flexible and creative thinking and don't stick to what the teacher teaches. Wang et al. (2011) stated that the most important things in the ability to think creatively mathematically are fluency, flexibility, originality, and elaboration. One aspect that influences students' mathematical creative thinking abilities when solving a mathematical problem is Self-Regulated Learning (SRL).

SRL is one of the most important factors that influence the learning process of students (Dabbagh & Kitsantas, 2013). Nugraheni et al. (2021) also stated that SRL is a predictor of student success in learning. According to Eladl & Polpol (2020) states that students' SRL has an influence on students' creative problem solving abilities. This is supported by Munahefi et al. (2022) which concluded that SRL had a positive effect of 85.4% on students' mathematical creative thinking abilities. This was reinforced by the research of Runisah & Ismunandar (2020) which obtained the result that there was a significant positive correlation between SRL and students' mathematical creative thinking abilities.

A teacher is required to have the ability to organize and choose the appropriate learning strategy to be used. One learning strategy that is thought to be effective for improving students' mathematical creative thinking abilities is through Creative Problem Solving (CPS) learning. CPS is a learning model that can be a means of developing creative thinking abilities (Maharani et al., 2015). CPS according to (Isaksen, 1995) consists of three main components, namely (1) Undestranding the Challenge; (2) Generating Ideas; and (3) Preparing Action.

CPS is a variation of problem solving learning with systematic techniques in organizing creative ideas to solve a problem (Situmorang & Gultom, 2018). This selection is because students are required to be accustomed to thinking creatively in developing the ideas they have when solving mathematical problems. Unlike other problem-solving methods, CPS places more emphasis on the

need to postpone judgment (decisions) on ideas from the solutions obtained until a final decision is made (Henriksen et al., 2017). According to Kim et al. (2019) the advantages of the CPS learning model are that it trains students to think and act creatively, because problems are presented at the beginning of learning and it gives freedom to students to look for directions for completion so that they can stimulate the development of students' thinking progress to solve problems appropriately. The habit of students using creative ideas in solving a problem is expected to help students develop their creative thinking abilities. In line with this Khalid et al. (2020) stated that CPS learning was able to improve creative thinking abilities and problem solving in learning mathematics.

The use of appropriate learning models in the learning process should be supported by appropriate assessments as well so that they are in accordance with the learning objectives that have been planned beforehand. One alternative assessment that can be used is in the form of a performance assessment. According to Stiggins in Masrukan (2017) states that performance assessment is a form of test in which students are asked to carry out special activities under the supervision of a teacher who will observe their performance and make decisions about the quality of the learning outcomes they show. Performance assessment can also assist teachers in maximizing their assessment of the learning process carried out by students directly because students are asked to carry out various kinds of activities that can support their learning process, so that without waiting for the lesson to finish the teacher can provide an accurate assessment. This is also supported by Tejeda & Gallardo (2017) who reveal that using performance assessments can determine whether students can relate their knowledge to situations that exist in real life. Peck et al. (2014) also reported that performance assessment can clearly increase students' understanding of their strengths and weaknesses. In addition, using a performance assessment can encourage students' interest in learning and activeness of students in learning (Masrukan & Elmagustilla, 2020).

Based on the description above, research will be carried out on the analysis of mathematical creative thinking abilities in terms of SRL in the CPS learning model with performance assessment.

2. Methodology of Research

The type of research used is mixed research (mixed method). The research design used was the pretest-posttest control group design. In this study, two classes were taken, namely the experimental class and the control class. The experimental class will be applied to the CPS learning model with performance assessment and the control class will be applied to the CPS Learning learning model. This study uses mixed methods with a sequential explanatory design which is a mixed method that has a larger quantitative portion than the qualitative one, and also has a stronger quantitative background than the others.

The population in this study were all class VIII students of SMP Negeri 1 Tayu Pati for the 2022/2023 academic year. The population in this study was randomly selected using Cluster Random Sampling and took 2 classes to be used as the experimental class and the control class. The research sample was class VIII A which applied the CPS learning model with performance assessment and class VIII B applied the learning model CPS. The subject taking technique in this study used a purposive sampling technique.

3. Finding/Results

3.1 Quality of Learning

The quality of learning that is assessed consists of: (1) the planning stage, (2) the implementation stage, and (3) the assessment stage. This planning stage is through an assessment carried out by three expert validators with a scale of 5. Learning tools and instruments that are validated include flow of learning objectives, teaching modules, worksheets, mathematical creative thinking test, self-regulated learning scales, observation sheets of learning implementation, student response questionnaires, and interview guidelines. Learning tools and instruments got the lowest score of 4.00 with good criteria and the highest score of 4.78 with very good criteria, so it can be concluded that the learning tools and instruments are valid and good for use in research.

At the implementation stage, a learning is said to be good quality if the learning observation sheet is in the minimal good criteria. The learning observation sheet obtained a score of 93.75% in first meeting with very good criteria, 95.31% in second meeting with very good criteria, and 95.31 in third meeting with very good criteria.

The quality of the assessment stages can be seen from student's responses sheets and the effectiveness of learning with the CPS learning model with performance assessment on mathematical creative thinking. The student response sheet to learning scored 70.75% with a good criteria. Before conducting the effectiveness test, the prerequisite test was first carried out, namely the normality test and different variance test using the help of R programming language. Normality test results obtained that the data comes from a normally distributed and has the same variance.

Based on the results of the research data obtained, classical completeness in this research if more than 75% of students who received CPS learning with a performance assessment obtained a score with a minimum limit of 70. Based on the output data using R, the *p-value* $0{,}02384 < 0{,}05$, so H_0 was rejected. This means that the proportion of completeness of students in CPS learning with performance assessment is more than 75%.

The next test is difference mean test which is used to determine whether the average mathematical creative thinking ability of students with CPS learning with performance assessment is better than the average creative thinking ability of students with CPS learning. Based on the output data using R, the *p-value* $1{,}192 \times 10^{-9} < 0{,}05$, so H_0 was rejected. This means that the average mathematical creative thinking ability of students using CPS learning with a performance assessment is better than the average results of students' mathematical creative thinking abilities using CPS learning.

The third test is difference proportion test which is used to determine the difference between the number of students who achieve mastery of creative thinking skills who are taught using CPS with performance assessment and the number of students who achieve mastery of creative thinking skills who are taught using CPS. Based on the output data using R, the *p-value* $1{,}143 \times 10^{-7} < 0{,}05$, so H_0 was rejected. This means that the proportion of mathematical creative thinking abilities of students who have completed learning using CPS with a performance assessment is better than the proportion of students' mathematical creative thinking abilities who have completed learning using CPS learning.

The final test is an improvement test conducted on two paired samples, namely the pretest and posttest of the experimental class by assuming that both data are normally distributed and have the same variance. Based on the output data using R, the *p-value* $9{,}919 \times 10^{-9} < 0{,}05$, so H_0 was rejected. This means that there is an average difference between pretest and posttest in the experimental class. Based on the results of the N-Gain test, it was found that 7 people or 20.59% of students experienced an increase in mathematical creative thinking ability in the high category, as many as 22 people or 64.71% of students experienced an increase in the medium category, and 5 people or 14.71% of students experienced an increase in the low category.

3.2 Mathematical Creative Thinking Ability High Self-Regulated Learning Category

S-01 and S-02 are subjects who have high self-regulated learning based on self-regulated learning questionnaires. Based on the test results, subjects S-01 and S-02 were able to write down what they knew and were asked about in the questions and were able to find the size of an obtuse triangle correctly so that the fluency indicator was met. When conducting interviews, fluency indicators were also fulfilled because S-01 and S-02 subjects knew the information contained in the questions and were able to explain how to solve them smoothly, precisely, and clearly.

Based on the test results, subject S-01 and subject S-02 were able to provide alternative answers from obtuse triangle sizes so that the flexibility indicator was fulfilled. When conducting interviews, the flexibility indicator was met because subjects S-01 and S-02 were able to provide more than one alternative answer regarding the possible sizes of obtuse triangles.

Based on the test results, subject S-01 and subject S-02 were able to create new ideas in giving answers without plagiarizing from his friends, this can be seen that the work of subjects S-01 and S-02 is different from the others so that the originality indicator is met. When conducting interviews, the originality indicator was met because subjects S-01 and S-02 were able to provide answers according to their own thoughts.

Based on the test results, subject S-01 and subject S-02 were able to explain the results of their work in detail on the answer sheet so that the elaboration indicators are met. When conducting interviews, the elaboration indicator was met because subject S-01 and subject S-02 was able to check back on the answers given and was sure that the answers were detailed.

3.3 Mathematical Creative Thinking Ability Medium Self-Regulated Learning Category

S-03 and S-04 are subjects who have high self-regulated learning based on self-regulated learning questionnaires. Based on the test results, subjects S-03 and S-04 were able to write down what they knew and were asked about in the questions and were able to find the size of an obtuse triangle correctly so that the fluency indicator was met. When conducting interviews, fluency indicators were also fulfilled because S-03 and S-04 subjects knew the information contained in the questions and were able to explain how to solve them smoothly, precisely, and clearly.

Based on the test results, subject S-03 and subject S-04 unable to meet the flexibility indicator because the alternative answers given were not appropriate. When conducting interviews, the flexibility indicator was not met because subject S-03 and S-04 was still unsure about providing alternative answers regarding the size of obtuse triangles.

Based on the test results, subject S-03 and subject S-04 were able to create new ideas in giving answers without plagiarizing from his friends, this can be seen that the work of subjects S-03 and S-04 is different from the others so that the originality indicator is met. When conducting interviews, the originality indicator was met because subjects S-03 and S-04 were able to provide answers according to their own thoughts.

Based on the test results, subject S-03 and subject S-04 were able to explain the results of their work in detail on the answer sheet so that the elaboration indicators are met. When conducting interviews, the elaboration indicator was met because subject S-03 and subject S-04 was able to check back on the answers given and was sure that the answers were detailed.

3.4 Mathematical Creative Thinking Ability Low Self-Regulated Learning Category

S-05 and S-06 are subjects who have high self-regulated learning based on self-regulated learning questionnaires. Based on the test results, subjects S-05 and S-06 were able to write down what they knew and were asked about in the questions and were able to find the size of an obtuse triangle correctly so that the fluency indicator was met. When conducting interviews, fluency indicators were also fulfilled because S-05 and S-06 subjects knew the information contained in the questions and were able to explain how to solve them smoothly, precisely, and clearly.

Based on the test results, subject S-05 and subject S-06 unable to meet the flexibility indicator because the alternative answers given were not appropriate. When conducting interviews, the flexibility indicator was not met because subject S-05 and S-06 was still unsure about providing alternative answers regarding the size of obtuse triangles.

Based on the test results, subject S-05 and subject S-06 were able to create new ideas in giving answers without plagiarizing from his friends, this can be seen that the work of subjects S-05 and S-06 is different from the others so that the originality indicator is met. When conducting interviews, the originality indicator was met because subjects S-05 and S-06 were able to provide answers according to their own thoughts.

Based on the test results, subject S-05 and subject S-06 unable to explain the results of his work in detail on his answer sheet so that the elaboration indicators have not been fulfilled. When conducting interviews, the elaboration indicator was not met because subject S-05 and S-06 did not recheck the answers given and was not sure that the answers were detailed.

4. Discussion

4.1 Quality of Learning

The quality of learning is a series of activities that can increase the competence of students. The quality of learning in this study was reviewed quantitatively and qualitatively. The learning planning stages, learning tools and research instruments are validated by expert validators. Based on the results of the validator's assessment, overall the tools and instruments that have been prepared are valid so that they can be used for research. This validity can be seen from the acquisition of scores given by 3 expert validators for each device in the good and very good categories, so that the devices that have been made by researchers are feasible to use in research. This is supported by

Danielson (2011) which states that a learning device is said to be valid if it is at least in the good category so that the device is suitable for use.

Stages of learning implementation, measuring the quality of implementing CPS learning with performance assessments is carried out through observing the implementation of learning. Implementation of learning is done 3 times meeting. The material taught in CPS learning with performance assessment is the Pythagorean theorem. In the first meeting students were taught about how to prove the truth of the Pythagorean theorem. In the second meeting, students were taught material on special types of triangles. The third meeting taught about Pythagorean triples. Each student meeting is given a stimulus in the form of problems related to real life and given a performance assessment sheet which is presented in the worksheets. Through the results of the observer's assessment, it can be seen that in first, second and third meetings, the average percentage of learning implementation was in the very good category. Based on the results of the assessment of the learning implementation sheet from the first meeting to the third meeting, it can be seen that CPS learning with performance assessment is of good quality. This is supported by Danielson (2011) who states that in the implementation of learning it is said to be of high quality if the learning implementation is at least in the good category.

The last stage of learning is the assessment stage. Stages of assessment, students are given a questionnaire of students' responses to learning. Based on the results of the student response questionnaire, the results obtained were that the majority of students gave a good assessment of the learning that had been implemented. The assessment stage also carried out an analysis of the results of mathematical creative thinking test data and the SRL scale of students. Students are given initial ability tests in the experimental class and control class. The results of the initial ability test showed that the average mathematical creative thinking ability of the experimental and control class students in solving mathematical creative thinking ability questions was almost the same. Based on the homogeneity test, information is obtained that the two classes have a homogeneous variance. Based on the average similarity test, it was concluded that the average test ability of the experimental and control class students in solving problems was not significantly different. This shows that students in the experimental class and control class have the same initial abilities.

The experimental class was given the SRL scale and the pretest of mathematical creative thinking before being given CPS learning with a performance assessment. Furthermore, CPS learning was carried out with a performance assessment followed by the provision of the mathematical creative thinking posttest and the SRL scale. The first test, namely classical completeness, showed that the proportion of experimental class students who scored 70 exceeded 75%. The second test is the average difference test between the experimental class and the control class. Based on the results of the average difference test, it was found that the average mathematical creative thinking ability of the experimental class students in solving questions was better than the mathematical creative thinking ability of the control class students. The next test was a test of different proportions which obtained the results of the proportion of mathematical creative thinking abilities of students who had completed learning in the experimental class was better than the proportion of students' mathematical creative thinking abilities who had completed learning in the control class. The fourth test, namely the improvement test, obtained the result that there was an

average difference between the mathematical creative thinking pretest and posttest in the experimental class. Based on the overall N-Gain average value of 0.48 or the increase in mathematical creative thinking ability is in the medium category. These statements show that CPS learning with performance assessment can be measured in quality. This is also supported by Agustina et al. (2023) which states that the use of the CPS model in the mathematics learning process is effective for students' mathematical creative thinking abilities.

The CPS learning syntax with performance assessment will guide students in the habit of thinking creatively in solving a given problem, while the initial goal of the performance assessment strategy is to give freedom to students to solve problems according to the students' own ideas. Panji Yudha (2018) states that using a performance assessment can improve student learning achievement, especially in junior high school geometry material. This learning model and supporting strategy will certainly develop students' creative thinking power with the freedom that students have. The reason for using the CPS learning model is also reinforced by Khalid et al. (2020) stated that CPS learning was able to improve creative thinking skills and problem solving in learning mathematics.

The causative factors of CPS learning with performance assessment can improve students' mathematical creative thinking ability because in the CPS model with performance assessment, students are accustomed to carrying out problem solving activities using various strategies or their own methods. CPS learning with performance assessment, students carry out group discussions to analyze problems and develop problem solving strategies. Through these discussion activities students can develop their creative thinking skills to find answers to the problems given. This is in accordance with Sriraman's research as cited by Shriki (2010) who found the fact that social interactions such as talking to people and exchanging ideas are important aspects in stimulating one's creative thinking.

CPS learning with performance assessment in the initial activities of students is given motivation as an effort to build their learning independence. Furthermore, students are given problems contained in an activity sheet called worksheets. The worksheets provided contains problems related to real life that are in accordance with the mathematical creative thinking ability indicators and is given a performance assessment sheet presented in the worksheets.

In addition to being given worksheets, students are also given quizzes to measure students' understanding after going through a series of activities on worksheets. The quizzes given in CPS learning with performance assessment are also questions that are in accordance with the mathematical creative thinking ability indicators. The habit of giving problems during learning provides a lot of experience for students to think creatively in the process of finding answers. This causes the students' mathematical creative thinking ability to be better in the experimental class.

4.2 Mathematical Creative Thinking Ability High Self-Regulated Learning Category

Based on the results of the study, in general students with high SRL categories are able to solve problems related to mathematical creative thinking abilities because SRL and mathematical creative thinking ability have a positive relationship (Al-kreimeen, 2014; Majdi et al., 2017). Runisah & Ismunandar (2020) also stated that students who have good SRL will improve their creative

thinking skills in solving problems. This is evident from the results of the work of students who are able to fulfill all indicators of mathematical creative thinking ability, namely fluency, flexibility, originality, and elaboration. The results of students' work when triangulated with interviews, students were able to answer each question convincingly according to what was written clearly and in detail.

Students with high SRL categories are able to achieve fluency indicators because according to Siswono (2011) students can be said to achieve fluency indicators if they can find information and are able to provide appropriate problem solving. This is evident from the results of the work and interview results that students with high SRL are able to find out the information contained in the questions and provide relevant answers to the questions.

Students with a high SRL category are also able to fulfill the flexibility indicator. According to Hendriana et al. (2017) students are said to meet the flexibility indicator if the ability to answer questions is able to use a number of varied ideas, can see problems from different perspectives, and look for different alternative solutions. This is shown by the many alternative answers given, such as questions number 1 and 2 students can provide other alternative answers. Students with a high SRL category find it easier to explore their abilities in finding new ideas to find alternative answers. Students do not experience difficulties in finding different alternative answers.

Students in the high SRL category are able to meet originality indicators. Menurnt Siswono (2011) states that an indicator of originality is achieved when students are able to spark original or unique ideas that come from themselves. This can be seen from the results of work number 1 and 2 students are able to provide answers according to the results of their own thinking about the size of obtuse triangles and primitive Pythagorean triples. This is supported by Al-kreimeen (2014) who states that students who have high SRL are able to achieve greater aspects of originality in creative thinking because it involves hard work in solving problems.

Students in the high SRL category are able to fulfill the elaboration indicators. According to Hendriana et al. (2017) students can be said to have achieved the elaboration indicator if they have the ability to develop ideas and add details of an object in detail. When confirmed through interviews, students are able to detail the answers given and check the results of the answers.

Based on the findings that have been made, it can be concluded that in general subjects with high SRL categories can fulfill all indicators of the ability to think creatively mathematically to the fullest. This finding is also supported by Munahefi et al. (2022) which states that students with high SRL have been able to achieve all indicators of the ability to think creatively mathematically, namely fluency, flexibility, originality, and elaboration. This is also supported by Ahmar (2016) who stated that the higher the students' SRL, the higher the achievement of their creative thinking abilities.

4.3 Mathematical Creative Thinking Ability Medium Self-Regulated Learning Category

Based on the results of the study, in general students in the moderate SRL category were only able to solve a number of problems related to creative thinking skills. This is evident from the results of the work of students who are able to meet the indicators of ability to think creatively mathematically, namely fluency, originality, and elaboration but are unable to fulfill the flexibility

indicators. The results of students' work when triangulated with interviews, students were able to answer each question convincingly according to what was written clearly and in detail.

Students in the medium SRL category are able to achieve fluency indicators because according to Siswono (2011) students can be said to achieve fluency indicators if they can find information and are able to provide appropriate problem solving. This is evident from the results of the work and interview results that students with moderate SRL are able to find out the information contained in the questions and provide answers that are relevant to the questions.

Students in the moderate SRL category are unable to achieve flexibility indicators because in solving problems students do not provide alternative answers. Students are still confused to find ideas in providing alternative answers. This finding is supported by Agustina et al. (2022) which stated that students in the moderate SRL category were unable to fulfill the flexibility indicator.

Students in the medium SRL category are able to meet originality indicators. Menurnt Siswono (2011) states that an indicator of originality is achieved when students are able to spark original or unique ideas that come from themselves. This can be seen from the results of work number 1 and 2 students are able to provide answers according to the results of their own thinking about the size of obtuse triangles and primitive Pythagorean triples.

Students in the SRL category are being able to fulfill the elaboration indicators. According to Hendriana et al. (2017) students can be said to have reached the elaboration indicator if they have the ability to develop ideas and add details of an object in detail. When confirmed through interviews, students are able to detail the answers given and check the results of the answers.

4.4 Mathematical Creative Thinking Ability Low Self-Regulated Learning Category

Based on the results of the study, in general students with low SRL categories are not fully able to solve several problems related to creative thinking skills because the lower the SRL of students, the lower the achievement of their creative thinking abilities (Ahmar, 2016). This is evident from the results of the work of students who were only able to meet the indicators of ability to think creatively mathematically, namely fluency and originality but were unable to fulfill the indicators of flexibility and elaboration.

Students with low SRL categories are able to achieve fluency indicators because according to Siswono (2011) students can be said to achieve fluency indicators if they can find information and are able to provide appropriate problem solving. This is evident from the results of the work and interview results that students with low SRL are able to find out the information contained in the questions and provide answers that are relevant to the questions.

Students with low SRL categories are unable to achieve flexibility indicators because in solving problems students do not provide alternative answers. Students are still confused to find ideas in providing alternative answers. This finding is supported by Agustina et al. (2022) which stated that students in the low SRL category were unable to fulfill the flexibility indicator.

Students with low SRL category are able to meet originality indicators. Menurnt Siswono (2011) states that an indicator of originality is achieved when students are able to spark original or unique ideas that come from themselves. This can be seen from the results of work number 1 and 2

students are able to provide answers according to the results of their own thinking about the size of obtuse triangles and primitive Pythagorean triples.

Students with low SRL categories were unable to meet the elaboration indicators because when confirmed through interviews, students were unable to detail the answers given and did not check the results of their answers. This finding is supported by Munahefi et al. (2022) which states that students with low SRL are unable to achieve indicators of the ability to think creatively and mathematically elaboration.

5. Conclusion

Based on the results and discussion of the research, the following conclusions can be drawn: (1) CPS learning with performance assessment has the quality in improving students' mathematical creative thinking abilities; (2) subjects with high SRL were able to fulfill all indicators of mathematical creative thinking abilities namely fluency, flexibility, originality, and elaboration; subjects with medium SRL only met fluency, originality, and elaboration; subjects with low SRL only met fluency and originality.

6. Recommendations

In this study, teachers need to know and pay attention to the level of self-regulated learning of students so that they can motivate students appropriately to achieve learning goals. The CPS learning model based with performance assessment can be used as material for consideration in making policies to improve the quality of learning. Students need to be more independent in learning so they can improve their cognitive abilities, especially mathematical creative thinking ability. For other researchers, the results of this study can be used as relevant references for subsequent research.

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