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Senior High School Students' Higher Order Thinking Skills in Solving Combinatorics Problems

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Abstract

Higher Order Thinking Skills (HOTS) refer to students' ability to solve problems by analyzing, evaluating, and creating. HOTS are essential for 21st century learning. Solving combinatorics problem troubleshooting requires HOTS. The aim of this research is to examine of senior high school students' higher order thinking skills in solving combinatorics problems. This descriptive research describes the analysis of senior high school students' higher order thinking skills in solving combinatorics problems. Class XII IPA 6 SMA Negeri 1 Trenggalek has a total of 21 students. Data was collected through a written test containing combinatorics problems and interviews. The results of the study show the senior high school students' higher-order thinking skills in solving combinatorics problems: 38% of the students have "excellent" performance; 14% are rated as good; 10% are classified as enough; 38% are classified as low; no one is very poor. The most common indicator of higher-order thinking skills was analyzing (58%), followed by evaluating (55%). The creating rate is the lowest at 47%. This study can develop students' higher order thinking skills and evaluation for teachers in implementing higher order thinking skills in school.

Keywords: HOTS (Higher Order Thinking Skills), Combinatorics Problem.

Abstrak

Higher Order Thinking Skills (HOTS) adalah kemampuan siswa untuk memecahkan masalah dengan cara menganalisis, mengevaluasi, dan mengkreasi atau mencipta. Pada pembelajaran abad ke-21, sangatlah penting dalam membangun kemampuan berpikir tingkat tinggi. Pemecahan permasalahan kombinatorika memerlukan kemampuan berpikir tingkat tinggi. Tujuan dari penelitian ini adalah untuk menganalisis kemampuan berpikir tingkat tinggi siswa SMA dalam menyelesaikan permasalahan kombinatorika. Penelitian ini merupakan jenis penelitian deskriptif dengan subjek penelitian yaitu 21 siswa dari kelas XII IPA 6 SMA Negeri 1 Trenggalek. Teknik pengumpulan data menggunakan tes tertulis mengenai permasalahan kombinatorika dan wawancara. Berdasarkan hasil penelitian, diperoleh hasil analisis kemampuan berpikir tingkat tinggi siswa SMA dalam menyelesaikan permasalahan kombinatorika adalah sebagai berikut: Proporsi siswa dengan kemampuan berpikir tingkat tinggi sangat baik adalah 38%; selain itu, 14% siswa memiliki jenis keterampilan berpikir tingkat tinggi yang baik; 10% kemampuan berpikir tinggi dianggap cukup; 38% siswa berkategori rendah, dan tidak ada siswa berkategori sangat rendah. Tingkat kemunculan tertinggi dari indikator analisis 58%. Dilanjutkan evaluasi 55%, dan indikator dengan tingkat penampilan terendah adalah kreasi, yaitu 47%. Penelitian ini dapat mengembangkan kemampuan berpikir tingkat tinggi siswa dan bahan evaluasi untuk guru dalam penerapan HOTS di sekolah.

Kata kunci: Kemampuan Berpikir Tingkat Tinggi, Permasalahan Kombinatorika

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INTRODUCTION

The National Education System of the Republic of Indonesia Law No. 20 of 2003 stipulates that education is a conscious attempt to create a learning environment and process that enables students to actively develop their spiritual potential. The quality of education is very important in a country because it is a benchmark for the progress of a nation (Tanujaya et al., 2017). According to the results of the Human Development Reports in 2017 regarding education issues, Indonesia's

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education index in that year was ranked 7th out of 10 ASEAN countries. In addition, in research released by CEOWORLD in 2020, Indonesia's education system is ranked 70th out of 93 countries. One of the cause of the low student achievement is the lack of development of higher-order thinking skills at schools. Therefore, teachers must be capable of designing HOTS assignments in order to achieve a hit Education (Ginting & Kuswandono, 2020). Therefore, one important abilties mastered by students are higher order thinking skills (Susanti et al., 2020).

HOTS has been incorporated into the curricula of some schools in different countries. (R. Assaly & M. Smadi, 2015). HOTS consists of collaborative, authentic, unstructured, and difficult problems (Weiss, 2003). Brookheart (2010) defines higher order thinking skills with the following three terms: a. HOTS is a transfer process; in the context of learning, students are able to apply what has been learned into new conditions without guidance or instructions from educators or others; b. HOTS is critical thinking; in the context of learning, students have the skills to think logically (reasonably), reflectively, and make decisions independently; c. HOTS is problem solving; students can solve real problems in real life which are generally unique; they are able to use typical and non-routine solving procedures. Bloom's revised taxonomy points out that the cognitive aspect is divided into two groups of thinking skills, including LOTS (Lower Order Thinking Skills) and HOTS (Higher Order Thinking Skills). LOTS include abilities in the knowledge domains, namely C1 (remembering), C2 (understanding), and C3 (applying) while for HOTS include abilities in the knowledge domains, namely C4 (analyzing), C5 (evaluating), and C6 (creating) (Anderson & Krathwohl, 2001).

Data shows that HOTS and problem-solving abilities of Indonesian students are still weak. Indonesia at PISA 2018 scored 371 in reading, 379 in mathematics and 396 in science. These scores decreased compared to PISA in 2015, in which Indonesia scored 397 in reading, 386 in mathematics, and 403 in science (OECD, 2019). The 2018 National Examination results show that the ability of students in HOTS such as reasoning, analyzing, and evaluating is still low (Kementrian Pendidikan dan Kebudayaan, 2019).

Students of this era need an early understanding of HOTS in order to prepare for the needs of the 21st century (Yoke et al., 2015). The main purpose of education is to provide students with the flexibleness to assume critically, to know what they do, and justify it supported their enlightened higher cognitive process (Zohar, 2008). Therefore, students have to be able to react quickly and effectively to changes. To solve problems, intellectual skills, the ability to analyze information and integrate different sources of knowledge are required. Critical thinking is the ability to think about what a person should do or think about (Lapuz & Fulgencio, 2020). Critical thinking patterns can also improve verbal and analytical skills. Clear and systematic thinking will improve the categorical ideas. It is beneficial in learning the way to analyze the structure of a text logically, and improve the power. In addition to building, it is also necessary to have an assessment to measure students' HOTS in solving a problem.

To measure the problem solving ability of students, a test is needed. The test used should be familiar to students so that they can apply problem-solving skills to solve mathematical problems. Mathematics is human activity (Freudenthal, 1991). The purpose of mathematics as a human activity is to allow people to rediscover mathematical ideas and concepts with the guidance of adults (Gravemeijer, 1994). One of the topics in mathematics that is appropriate to measure higher order thinking skills is combinatorics problems. Combinatorics could be described as the art of arranging objects according to determined rules (Cameron, 1994). In addition, solving combinatorics problems requires critical and creative thinking skills (Dosinaeng, 2019). HOTS has two components, critical and creative thinking skills (Kwangmuang et al., 2021). Critical thinking skills are needed to build work procedures based on a continuous reasoning process. Creative thinking skills are needed to build connections between mathematical concepts and or between disciplines to solve given mathematical problems.

Based on the problems that have been described, HOTS is needed in 21st-century learning. However, many mathematics lessons in schools have not used HOTS. In this study, we describe the analysis of each HOTS indicator, namely analyzing, evaluating, and creating in each category of students. This has never been discussed in previous studies. Therefore, the purpose of this research is is to describe the analysis of senior high school students' higher order thinking skills in solving combinatorics problems the categories of excellent, good, enough, low, and very poor. So, this study can develop students' higher-order thinking skills and evaluation for teachers in implementing.

METHODS

This study is descriptive qualitative research. The research design was chosen because this study describes the analysis of senior high school students' higher-order thinking skills in solving combinatorics problems. The analysis of higher-order thinking skills is known based on tests and interviews. So, the data obtained from this study is descriptive data in the form of writing and according to the actual situation. Moleong (2013) defines qualitative analysis as research that intends to grasp the development of what is practiced by the research subject, including behavior, perception, motivation, action, et al. represented within the kind of words and language during a special context naturally and by utilizing numerous natural.

The subjects of this study are 21 students from the XII Science major 6 SMA Negeri 1 Trenggalek. They are 10 males and 11 femels. The subject was chosen because the students had received the topic of combinatorics and they have not known the category of HOTS they had through the stages of analyzing, evaluating and creating.

This study used test items and interview guidelines. The test questions are in the form of two questions that have been adjusted to indicators from Bloom's taxonomy to determine students' HOTS. The material used in this test is combinatorics problems regarding the rules of counting. The interview guide contains an outline of the questions asked by the researcher, namely the information that can be known based on the questions given and the steps taken by students in answering the test questions. The following are indicators of test and interview questions presented in Table 1.

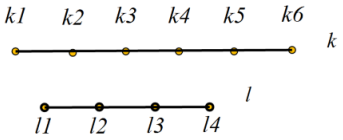
Table 1. Question and interview indicators

Higher Order Thinking Skills	Indicators
Analyzing	Students are able to classify information to find out its relationship.
	Students are able to distinguish cause and effect.
	Students are able to identify and connect elements in an information so that they get a hierarchy.
Evaluating	Students are able to provide an assessment of ideas, solutions, and methodologies
	Students are able to make criticisms, hypotheses, and conduct tests.
	Students are able to accept or reject a statement.
Creating	Students are able to make general conclusions from an idea or perspective on something.
	Students are able to design a strategy to solve the problem.
	Students are able to organize parts or elements into the right strategy.

The combinatorics test used in this study comprises two essay questions. This test is made with indicators of higher order thinking skills based on Bloom's taxonomy of analyzing, evaluating and creating. Before being given to students, the combinatorics test questions must go through a validation stage by two lecturers of mathematics education at the University of Jember. The combinatorics test questions are presented in Figure 1.

1. SMA Tunas Harapan sedang mempersiapkan perwakilan siswanya untuk mengikuti Olimpiade Sains Nasional (OSN) yang terdiri dari beberapa cabang yaitu matematika, fisika, kimia, dan biologi. Pada kelas XI MIPA 1 jumlah siswa yang mewakili cabang matematika dan kimia sebanyak 7 siswa dan pada kelas XI MIPA 2 selisish siswa yang mewakili cabang fisika dan biologi adalah 2 siswa. Siswa yang mewakili cabang kimia sebanyak 4 siswa dan jumlah siswa yang mewakili sekolah untuk mengikuti OSN sebanyak 13 siswa. Suatu hari seluruh siswa perwakilan sekolah yang mengikuti OSN melakukan rapat. Mereka diposisikan duduk melingkar dengan syarat siswa yang mewakili cabang yang sama harus duduk berdampingan. **Banyak cara mengatur susunan duduk mereka adalah 6 cara**. Apakah pernyataan yang bercetak tebal benar? (Jika benar buktikan kebenarannya, sedangkan jika salah berikan pernyataan yang benar beserta alasan)

2. Perhatikan gambar berikut!



Diketahui $k1, k2, k3, k4, k5, k6$ adalah titik yang terletak pada garis k, sedangkan $l1, l2, l3, l4$ adalah titik yang terletak pada garis l. Jika titik-titik pada garis k dilanjutkan hingga n titik dan titik-titik pada garis l juga dilanjutkan hingga $n-2$ titik, sedangkan titik-titik pada garis k dihubungkan dengan titik pada garis l sehingga membentuk segitiga. Tentukan formula untuk menghitung banyak segitiga dengan menghubungkan titik-titik tersebut!

Figure 1. Combinatorics test

Validation of test items was carried out to determine the suitability of the questions made with indicators of higher order thinking skills based on Bloom's taxonomy. The validation of the test questions obtained an average of 3.625 from a scale of 1 to 4. Therefore, it is in the very valid category and can be used. Based on the results of the validation of the interview guidelines, an average of 3.6 was obtained from a scale of 1 to 4. Therefore, it was in the very valid and usable category.

The next stage is data collection which begins with the distribution of combinatorics test questions to 21 students of class XII Science major 6 SMA Negeri 1 Trenggalek through Google Classroom, so that students can work online and the collection time is in accordance with the instructions for working on the questions. After all students answered the test, the student's answers were assessed. The results of the test were used as a basis for grouping based on the HOTS category according to the International Center for the Assessment of Higher Order Thinking.. The categorization of HOTS values is presented in Table 2 as follows :

Table 2. Categorization of HOTS

Score	Category
81 – 100	Excellent
61 – 80	Good
41 – 60	Enough
21 – 40	Low
0 – 20	Very Poor

In each category of higher order thinking skills, two students were randomly selected to represent each category in the interview phase which aims to confirm students' answers. In addition, the interview was also aimed at finding information about the representation or answers that have been written based on the combinatorics test.

The data analyzed were the results of the combinatorics test and the results of interviews from the interview transcripts. The research subjects interviewed were coded as follows: SSB code for students in the excellent category, SB code for students in the good category, SC code for students in the enough category, SK code for students in the low category, and SSK code for students in the very poor category.

RESULTS AND DISCUSSION

Combinatorics test questions were given to students of SMA Negeri 1 Trenggalek through google classroom, so that the students can work online and the collection time was in accordance with the instructions for working on the questions. The results of the analysis of combinatorics test questions from 21 students are presented in Table 3 below:

Table 3. Results of combinatorial test analysis

Category	Students	Percentage
Excellent	8	38%
Good	3	14%
Enough	2	10%
Low	8	38%
Very Poor	0	0%

Based on the results of the data analysis above, two students were from each category. There were 8 students who participated in interviews in order to analyze the senior high school students' higher order thinking skills in solving combinatorics problems. The result of analysis of answers to test and interview questions which include three elements of higher-order thinking skills, which are analyzing, evaluating, and creating in terms of the excellent, good, enought, low, and very poor categories can be observed in Table 4 below.

Table 4. Analysis of higher order thinking ability

Aspect	Category	Percentage	Average
Analyzing	Excellent	95%	58%
	Good	87%	
	Enough	55%	
	Low	54%	
	Very Poor	0%	
Evaluating	Excellent	91%	55%
	Good	83%	
	Enough	50%	
	Low	50%	
	Very Poor	0%	
Creating	Excellent	88%	47%
	Good	57%	
	Enough	50%	
	Low	39%	
	Very Poor	0%	

Result SSB (Students' Excellent Category)

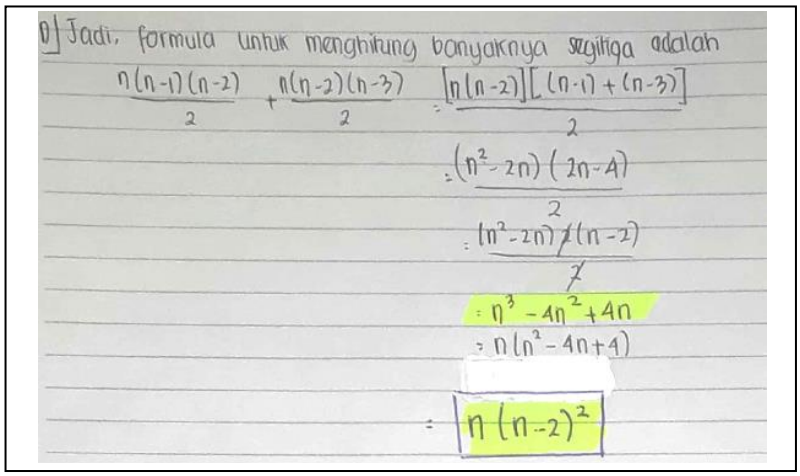


Figure 2. SSB's answer

Based on Figure 2, SSB is able to state the information obtained and use that information to design a problem solution.

The following are the results of the interview with the researcher (P) with.

PSSB03 : *"How do you convert the problem into combinatorics variables?"*

SSB03 : *Because in the question it is stated that they sit in a circle with a note that each representative of the competition sits side by side, it is considered that one competition is one object so that* $n = 4$. *However, each student in each competition also moves, resulting in permutations in each competition, namely mathematics* $n = 3$, *physics* $n = 4$, *chemistry* $n = 4$ *and biology* $n = 2$*"*

PSSB06 :*"Explain the steps you used to solve the problem!"*

SSB06 :*"The first is to find how many students are in each field using substitution and elimination. After that, find permutations of each competition. Next find cyclic permutations and the last is finding many ways to sit using the multiplication rule."*

PSSB09 :*"What conclusion after solving the problem?"*

SSB09 :*"The statement in bold is wrong because the way to sit is* 41472 *ways."*

SSB is able to state the information obtained, mention what is known and what is asked in the question, and can change the problem into combinatorics variables as shown in the interview snippet of SSB03. SSB is also able to provide conclusions in the form of rejection of a statement on the question and provide the right reasons and provide the correct statement as shown in the interview erexcpt of SSB09.

Result SB (Students' Good Category)

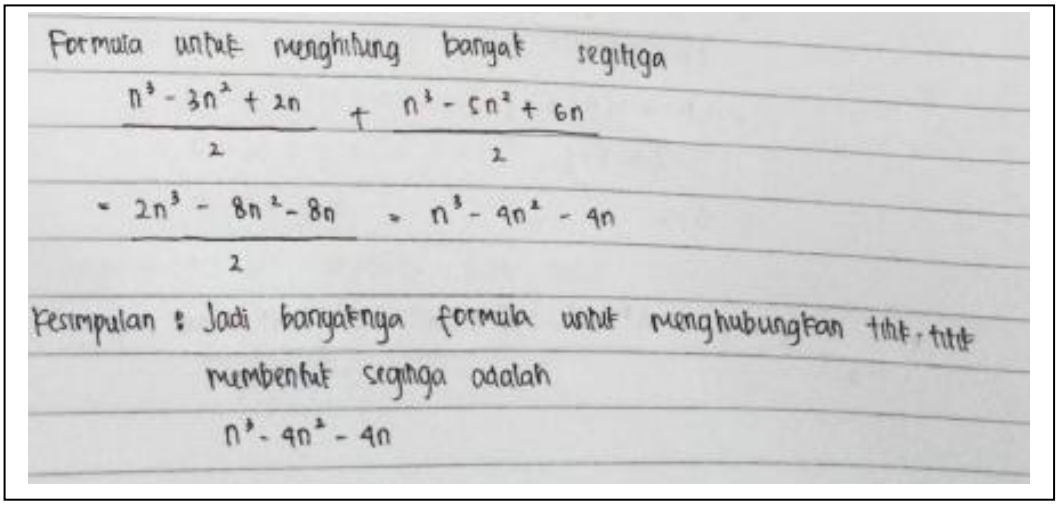


Figure 3. SB's answer

Based on Figure 3, SB is able to state the information obtained and use that information to design a problem solution as shown in Figure 3.

The following are the results of the interview with SB.

PSB03 :*"How do you convert the problem into combinatorics variables?"*

SB03 :*"When sitting in a circle* $n = 4$*, how to arrange mathematics* $n = 3$*, how to arrange physics* $n = 4$*, how to arrange chemistry n=4 and how to arrange biology* $n = 2$*."*

PSB06 :*"Explain the steps you used to solve the problem!"*

SB06 :*"The first is to find a way for students to sit in a circle and then find a way to arrange everyone's seating"*

PSB09 :*"What conclusion after solving the problem"*

SB09 :*"The way students sit is* 41472 *ways"*

SB is able to state the information obtained, has not been able to mention what is known and is able to mention what is asked in the question, and can change the problem into combinatoric variables as shown in the interview snippet of SB03. SB also has not been able to provide a conclusion in the form of rejection of a statement in the question and provide the right reasons and provide the correct statement as shown in the interview erexcpt of SB09.

Result SC (students' enough category)

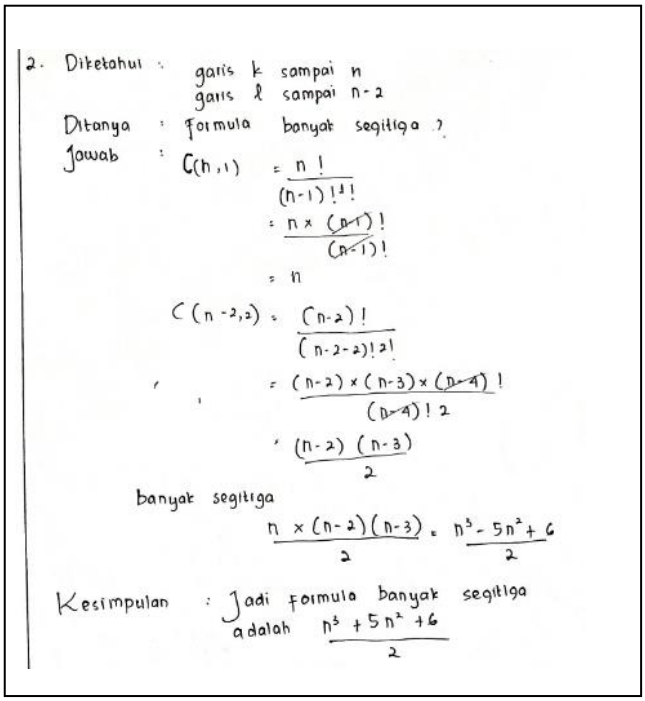


Figure 4. SC's answer

Based on Figure 4, SC is able to state the information obtained and use the information to design a problem solution but the results obtained have not been able to solve a problem.

The following are the results of the interview with SC.

PSC03 :*"How do you convert the problem into combinatorics variables?"*

SC03 :*"Since there are 4 competitions then* $n = 4$*"*

PSC06 :*"Explain the steps you used to solve the problem!"*

SC06 :*"Using cyclic permutations."*

PSC09 : "*What conclusion after solving the problem"*

SC09 :*"True statement. There are 6 ways to sit"*

SC is able to state the information obtained, has not been able to mention what is known and is able to mention what is asked in the question, and can change the problem into combinatorics variables as shown in the SC03 interview excerpt. SC has not been able to provide a conclusion in the form of rejection of a statement in the question and provide the right reasons and provide the correct statement as shown in the interview erexcpt of SC09.

Result SK (Students' Low Category)

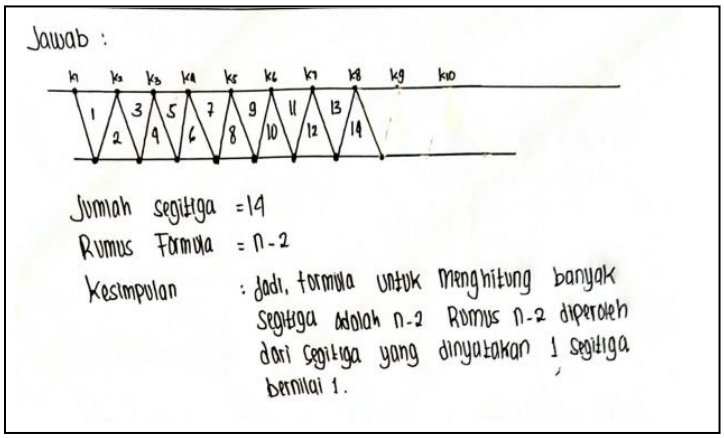


Figure 5. SK's answer

Based on Figure 5, SK is able to state the information obtained and use the information to design a problem solution but the results obtained have not been able to solve a problem.

The following are the results of the interview with SK.

PSK03 :*"How do you convert the problem into combinatorics variables?"*

SK03 :*" competitions is n"*

PSK06 :*" Explain the steps you used to solve the problem!"*

SK06 :*" Looking for members of mathematics, physics, chemistry, and biology and then permutations."*

PSK09 :*" What conclusion after solving the problem"*

SK09 :*" True statement. There are 6 ways to sit"*

SK1 is able to state the information obtained, has not been able to mention what is known and is able to mention what is asked in the question, and can change the problem into combinatorics variables as shown in the SK03 interview excerpt. SK has not been able to provide a conclusion in the form of rejection of a statement on the question and provide the right reasons and provide the correct statement as shown in the SK09 interview excerpt.

The excellent category, the percentage of evaluating, analyzing and creating aspects is very high. These data are in accordance with research conducted by Hasyim & Andreina (2019) that students in the excellent category fulfill the indicators of analyzing, evaluating, to creating. Students in the excellent category in analyzing aspects are able to classify information to find out its relationship, distinguish cause and effect, identify and connect elements in information so that they get a hierarchy. In the evaluating aspect, students are able to provide an assessment of ideas, solutions, and methodologies, make criticisms, hypotheses, and conduct tests, accept or reject a statement. In the aspect of creating, students are able to make general conclusions from an idea or

perspective on something, design a strategy to solve the problem, organize parts or elements into the right strategy.

In the good category, it is known that the percentage of analyzing and evaluating aspects is very high, while creating is high. The data is in accordance with research conducted by Hasyim & Andreina (2019) Students in the good category to meet the indicators of analyzing, evaluating, to creating. Students in the good category in analyzing aspects are able to classify information to find out its relationship, distinguish cause and effect, identify and connect elements in information so that they get a hierarchy. In the evaluating aspect, students are able to provide an assessment of ideas, solutions, and methodologies, make criticisms, hypotheses, and conduct tests, accept or reject a statement. In the aspect of creating, students are able to make general conclusions from an idea or perspective on something and design a strategy to solve the problem, but have not been organize parts or elements into the right strategy. This is because students have not been able to correctly answer the conclusions obtained after solving the problem and do not find other alternatives to complete the answer.

The enough category is dominated by the analyzing and evaluating. These data are in accordance with research conducted by Hasyim & Andreina (2019) Students in the enough category to meet the indicators of analyzing and evaluating. Students in this category aspect are able to classify information to find out its relationship, distinguish cause and effect, but are not yet fully able to identify and connect elements in the information so that they get a hierarchy. This is because students are not fully able to explain how to change the problem into combinatorics variables. In the evaluating aspect, students are able to provide an assessment of ideas, solutions, and methodologies, but have not been fully able to make criticisms, hypotheses, and conduct tests, accept or reject a statement. This is because students have not been able to explain all the steps used in solving the problem. In the aspect of creating, students are able to make general conclusions from an idea or perspective on something and design a strategy to solve the problem, but have not been able to organize parts or elements into the right strategy. This is because students have not been able to correctly answer the conclusions obtained after solving the problem and do not find other alternatives to complete the answer.

In the low category, it is known that the percentage of analyzing aspects dominates compared to other aspects. These data are in accordance with research conducted by Hasyim & Andreina (2019) Students in the low category to meet the analytical indicators. Students with low category lacking in analyzing aspects are able to classify information to find out its relationship, distinguish cause and effect, but are not yet fully able to identify and connect elements in the information so that they get a hierarchy. This is because students are not fully able to explain how to change the problem in the problem into combinatorics variables. In the evaluating aspect, students are able to provide an assessment of ideas, solutions, and methodologies, but have not been fully able to make criticisms, hypotheses, and conduct tests, accept or reject a statement. This is because students have not been able to mention all patterns of completion from the information obtained and students have not been

able to explain the steps used in solving these problems. In the aspect of creating, students are able to make general conclusions from an idea or perspective on something, but have not been able to design a strategy to solve the problem and organize parts or elements into the right strategy. This is because students have not been able to correctly answer the conclusions obtained after solving the problem and do not find other alternatives to complete the answer.

There are no students in the poor category. These data are in accordance with research conducted by Prasetyani et al. (2016) which states that there are no students in the very poor category. This shows that the students are at least able to go beyond the analytical aspect by knowing the information given to the question and knowing what is known and what is asked in the question.

The average on the analyzing aspect, has the highest percentage of 58%. The data is in accordance with previous research Prasetyani et al. (2016) which states that the analyzing indicator has the highest percentage of occurrences. This shows that students in solving combinatorics problems are able to examine and parse information appropriately, but there are students who have not been able to formulate problems and provide appropriate completion steps..

The average in evaluating aspects, has a percentage of 55%. The data is in accordance with previous research Prasetyani et al. (2016) which states that the evaluating indicator has a lower percentage of occurrence than the analyzing indicator. This is because not all students are able to assess, deny, or support an idea and provide reasons that can strengthen the answers obtained correctly.

The average percentage of creating is a percentage of 47%. The data is in accordance with previous research Prasetyani et al. (2016) which states that the indicator with the lowest percentage of occurrences is creation. This is because creativity is the highest indicator of higher order thinking skills. Few students are able to design ways to solve a problem or combine information into the right strategy.

CONCLUSION

The results of combinatorics test given to 21 students of SMA Negeri 1 Trenggalek, show that the senior high school students' higher order thinking skills in solving combinatorics problems are as follows: 38% of students have "excellent" performance; 14% are rated as good; 10% are classified as enough; 38% are classified as low; no one is very poor. The most common indicator of HOTS was analyzing as 58%, followed by evaluating with 55%. At the same time, the creating rate is the lowest at 47%.

It is recommended that further research, expands the topic of combinatorics test questions so that the research can future analyze senior high school students' higher order thinking skills in solving combinatorics problems.

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