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Development of hots mathematic problems (higher order thinking skills) Based on Krulic & Rudnick Taxonomy

Suryo Widodo[1*], Yuni Katminingsih[2], Nurwiani[3]

[1]Program Studi Pendidikan Matematika, Universitas Nusantara PGRI Kediri. Jalan KH. Acmad Dahlan No 76 Kota Kediri, Indonesia.
[3]Jurusan Pendidikan Matematika, STKIP PGRI Jombang. Jl. Patimura III/20 Jombang jawa timur, Indonesia

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* Korespondensi Penulis.
E-mail: suryowidodo@unpkediri.ac.id*

Abstract: The lack of availability of HOTS math questions in the field makes it difficult for teachers to teach students higher order thinking skills. Most of the hots questions developed were based on Bloom's taxonomy revised by Anderson et al. This study aims to produce valid and reliable HOTS questions and to measure students' higher-order thinking skills. This study uses a Tessmer model development research. This development model consists of 2 stages, namely (1) the preliminary stage and (2) the formative evaluation. Instrument testing was carried out in class X MIPA E SMA Negeri 1 Kediri. The data collection instruments included a question grid, a HOTS class X maths question sheet based on Krulik-Rudnick's, a validation sheet, and a question readability questionnaire. The data analysis technique uses item analysis which consists of validity, reliability, level of difficulty, and distinguishing power. This research has produced 11 items that are valid, practical, and reliable. In addition, this study produced a reliable item with a Cronbach's Alpha value of 0.921. The results of the test questions concluded that the high-order thinking skills (HOTS) of class X students in mathematics were good with an average score of 33.17.

Keywords: *HOTS mathematics problem; Formative evaluation; Taxonomy Krulik & Rudnik*

INTRODUCTION

Mathematical problems are instruments for measuring achievement indicators in mathematics learning. The purpose of using math problems is to increase understanding to master cognitive levels in learning, especially by introducing HOTS (Higher Order Thinking Skills) to students (I. W. Widana, 2017).

The achievement of Indonesian students' learning achievement in mathematics in 2012, 2015, and 2018 PISA studies is still far from satisfactory. Based on the test results, the performance of Indonesian students is still low. Indonesia's 2012, 2015, and 2018 PISA score data are presented in the following table:

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Table 1. Indonesia's 2012, 2015 and 2018 PISA scores, and rankings

	Scores	Peringkat
Mathematics 2012	375	64 out of 65 countries
Mathematics 2015	386	63 out of 72 countries
Mathematics 2018	379	73 out of 79 countries

(Hewi & Shaleh, 2020; OECD, 2016, 2019)

From observations, the report from the OECD shows a low level of basic literacy, especially in mathematics. This also shows that the ability of Indonesian students is low and unfamiliar with questions to improve higher-order thinking skills and familiarity with routine LOTS (Lower Order Thinking Skills) questions. It is important to give HOTS questions to students (Brookhart, 2010). This is because HOTS questions can improve the quality of education (Brookhart, 2014). However, students think that HOTS questions are difficult to solve (Abdullah, Abidin, & Ali, 2015; Chinedu & Kamin, 2015). This is because students rarely get practice solving HOTS questions during class learning. This is following the findings of Khan (2011) that students were only given questions at the LOTS level, even questions at the evaluation stage were never given to students (Khan & Inamullah, 2011). Likewise Sangpom (2016), students are accustomed to being taught by providing explanations, formula rules, and memorization theory (Sangpom, Suthisung, Kongthip, & Inprasitha, 2016)

Anderson and Krathwohl have revised Bloom's Taxonomy known as Revised Bloom Taxonomy, which is remembering (C1), understanding (C2), apply (C3 / apply), analyzing (C4), evaluating (C5), and creating (C6) (Brookhart, 2010; Churches, 2007; Forehand, 2010; Katminingsih, 2012). The last three levels of the taxonomy are called higher-order thinking skills (hots). According to PISA, it must involve three components, namely, context, content, and competence in making hots questions. Mathematical questions are suitable for measuring the level of thinking C1, C2, and C3 using routine questions and measuring higher-order thinking skills using non-routine questions. Routine problems usually include applying a mathematical procedure that is the same or similar to something just learned. In non-routine problems, arriving at the correct procedure requires more in-depth thinking. Non-routine problems are more complex than routine problems, so solving problems may not emerge immediately and require a high level of creativity and originality from the problem solver.

One form of non-routine questions that can be developed is the HOTS class X math problem based on the level of thinking by Krulik & Rudnick, which allows students to improve their high-order thinking skills in solving math problems.

The ability to think based on Krulik & Rudnick (Krulik & Rudnick, 1999; Muchtadi, 2016; S Widodo, 2015) is divided into 4 (four) levels, namely recall thinking, basic thinking, critical thinking, and creative thinking. For critical thinking and creative thinking it is the ability to think at a high level. The steps for solving problems based on Krulik & Rudnick's level of thinking above are an illustration of how the teacher teaches students to think critically and creatively, which is included in the HOTS realm. However, the facts in the field are very minimal in the availability of questions that can measure higher-order thinking skills (Johar,

Yusniarti, & Saminan, 2018). Many researchers have produced math HOTS problems, but they are based on Bloom's revised taxonomy (Nalurita, Sutinah, & Rahaju, 2005; Lewy, 2013; Zaenal Arifin & Retnawati, 2017; Cahyani, Syaban, & Ridha, 2019; Rahmawatiningrum, Kusmayadi, & Fitriana, 2019; Wulandari & Duskri, 2020). The development of high-order thinking skills of students will result in increased students' skills in mathematics and the ability of students to increase non-routine problems that require higher-order thinking skills. For eight years, the 2013 Curriculum has been applied to all levels of education, but the problem is that most schools have not fully implemented the learning process as expected in the curriculum (Suryo Widodo & Katminingsih, 2020). This is shown by the existence of the learning assessment process of students in the realm of knowledge by providing practice questions. The teacher still tends to give questions that only test the memory aspect and does not train students' higher-order thinking skills, especially in mathematics subject matter. This is because the teacher's ability to develop HOTS questions is still lacking (Cayani & Saltifa, 2021). Therefore, the researcher wants to produce HOTS questions through research on the Development of Mathematical Problems HOTS (Higher Order Thinking Skills) class X ala Krulik & Rudnick.

METHOD

Research Subjects and Research Locations

The research was conducted in the even semester of the 2019/2020 academic year. The research subjects were students of class X MIPA E SMA Negeri 1 Kediri. The research subjects were 36 people consisting of 16 men and 20 women.

This study used a development research model or Development Research Type Formative Evaluation (R & D), in which the researcher developed a class X HOTS math problem ala Krulik & Rudnick. This research refers to the model developed by (Tessmer, 1993). The advantage of the formative evaluation model is that the process of designing questions as an assessment instrument is carried out by prototyping, namely the implementation of analysis, planning, and implementation phases simultaneously and repeatedly. The following are several stages in this development research:

Preliminary stage

At this stage, the researcher communicates with the principal and mathematics teacher who is used as the research location, prepares the necessary materials, such as the X grade mathematics textbook used in the school where the research is carried out, and identifies the research location (by paying attention to the school as a favorite school) and research subjects and set the research schedule.

Self Evaluation Stage

Analysis

At this stage, the researcher conducted a material analysis. This aims to determine the material taught in class X as a comparison with higher-order thinking indicators on the questions to be developed**.**

Design

At this stage, the researcher designed the questions based on Krulik & Rudnick's higher-order thinking indicators (Krulik & Rudnick, 1999), in Table 2.

Table 2. Krulik & Rudnick HOTS indicator

Critical Thinking	Creative Thinking
Organizing	Synthesize ideas
Associating	Building ideas
Analysing	Implement ideas
Evaluating	

Design this product as a prototype. Of the seven indicators of higher-order thinking based on Krulik & Rudnick's 14 items can be developed in the form of descriptions.

Prototyping (validation, evaluation, and revision)

At this stage, the prototype will be tested in parallel with the experts and one of the following students:

Expert Review and One-to-one

The first prototype that has been designed is then given to the material experts and a student in parallel. At the expert review stage, the first prototype will be scrutinized, assessed, and evaluated by experts. Often called the construction validity test. Experts are asked to provide suggestions and responses on the validation sheet, which has been tested for validity using a percentage of agreement, and a value of more than 75% is obtained and as material for revising the first prototype and stating that the first prototype is valid. The expert referred to here is a fellow mathematics education study program lecturer who has a doctoral qualification.

In the One-to-one stage, the researcher tested the first prototype on a student as a tester. The results of student comments will be used as material for revision.

Small Group

The results of the revision decision on the first prototype will produce the second prototype. Then the second prototype will be tested on 5 (five) X grade high school students (non-research subjects outside the sample field test).

At this stage, the five students were asked to work on the questions. Based on the test results and student comments will be used as revision material and determine the practicality of the questions. To obtain data and see the practicality of hots questions, refer to Anisah's research (2011) which includes the clarity and legibility of the questions (Anisah, Zulkardi, & Darmowijoyo, 2011)

Field Test

The suggestions and comments for the small group were used as the basis for revising the second prototype. The results of the revision of the second prototype resulted in a third prototype. The third prototype was tested on research subjects, namely students of class X MIPA E SMA Negeri 1 Kediri.

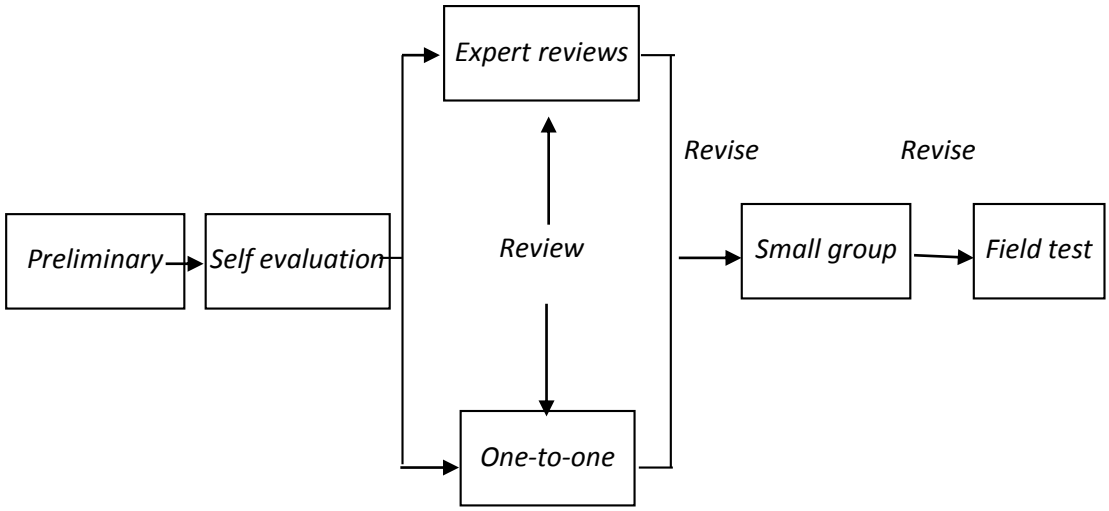


Diagram 1. The development stage of a formative test (Tessmer, 1993)

Data Collection Instruments

The research instruments used in this study were as follows: (1) Expert Validation Sheet, (2) Student Questionnaire Sheet, (3) a set of Class X HOTS math problems based on Krulik & Rudnick.

Data analysis technique

The test results analysis technique includes testing the validity, reliability, difficulty level, and distinguishing power. The validity test uses the formula percentage of agreement. As for the reliability test (Z Arifin, 2012), using the formula:

$$\alpha = \frac{R}{R-1}\left(1-\frac{\sum \sigma_i^2}{\sigma_x^2}\right)$$

Analysis of items for difficulty level (Z Arifin, 2012) using the following formula:

$$TK = \frac{average}{maximum\ score\ of\ each\ question}$$

Analysis of items for difficulty level (Z Arifin, 2012) using the following formula:

Where:

TK = level of difficulty

analysis of items for distinguishing power of questions (Z Arifin, 2012) using the following formula:

$$DP = \frac{(\bar{X}\ \text{upper group}) - (\bar{X}\ \text{lower group})}{\text{maximum score}}$$

Where:

DP = Discriminatory Power

Meanwhile, to measure students' higher-order thinking skills using a formula:

$$\text{Student scores} = \frac{\text{scores obtained by students}}{\text{maximum score}}$$

The test result data is then analyzed to determine the average final score then converted into qualitative data to determine the category of students' higher-order thinking skills. The categories for each indicator of the ability to think creatively are divided into four levels with a minimum score of 0 to a maximum of 6 with an interval length of 1.5.

Table 3a. Category of each indicator of the Student's Higher-Order Thinking Ability

Nilai siswa	Level of higher-thinking Ability of Students
4.6 – 6	Very good
3.1 – 4.5	Good
1.6 – 3	Pretty good
0 – 16.5	Not good

The higher-order thinking skills category is divided into four levels with a minimum score of 0 to a maximum of 66 with an interval length of 16.5.

Table 3b. Category Level of higher-thinking Ability of Students

Nilai siswa	Level of higher-thinking Ability of Students
49.6 – 66	Very good
33.1 – 49.5	Good
16.6 – 33	Pretty good
0 – 16.5	Not good

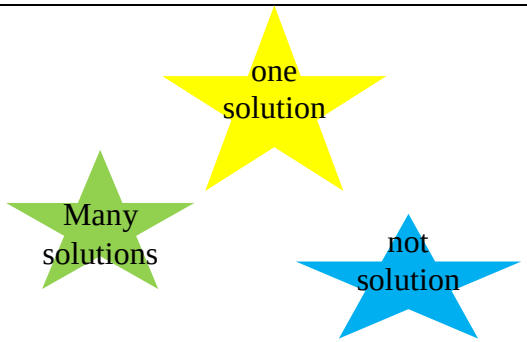
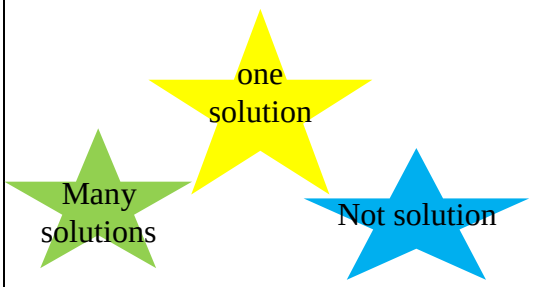
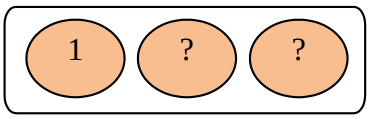
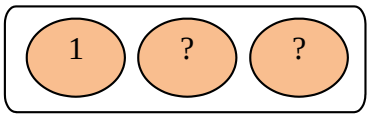
RESULTS AND DISCUSSION

Prototyping

Researchers provide prototype I to experts and a student. Responses and suggestions from experts are used as material for revision. In one-to-one time, the researcher looked at the difficulties experienced by students while working on the questions. It is also used for consideration. Based on one-to-one and expert review, the revision of prototype I resulted in a decision, namely correcting several errors in writing the question sentences and clarifying some of the question sentences, especially questions number 2, 3, 4, and 11.

Table 4. Prototype of questions before and after repair

Before the trial	After the trial
Fani is playing guess the correct star where each star contains an answer option. The first question as follows: Given a system of linear equations for the following three variables: x + y + z = 2 .....equation 1 2x + 2y + 2z = 3 .....equation 2 4x + 4y + 4z = 4 .....equation 3 Determine is the set of solutions for the SPLTV?	Fani is playing guess the correct star where each star contains an answer option. For the first question as follows: Given a system of linear equations for the following three variables: x + y + z = 2 .....equation 1 2x + 2y + 2z = 3 .....equation 2 4x + 4y + 4z = 4 .....equation 3 Determine is the set of solutions for the SPLTV?

Before the trial	After the trial
 Help Fani to choose the right star color!	 What color is the star card with the correct answer? Explain your reasons!
Tina finds a suitcase with a secret code number to open it.  The secret code number can be cracked if it is able to find a solution to the following problems: I am a member of the set of regions resulting from the function $f: x \rightarrow x$ - 5 from the set P = {6,7,8}. What is the next two-digit code number?	Tina finds a suitcase with a secret code number to open it.  The secret code number can be cracked if it is able to find a solution to the following problems: I am a member of the set of regions resulting from the function $f: x \rightarrow x$ - 5 from the set P = {6,7,8}. Help Tina to complete the three code numbers!

Small Group

The second prototype was tested on five students. Students are asked to work on the questions in stages to adjust the time needed to work on the questions needed and provide comments.

LEMBAR KOMENTAR SISWA

Menurut saya soalnya menarik dan kreatif, soalnya yang diberikan tidak pernah diberikan guru (soalnya beda/ tidak biasa), soalnya memiliki banyak cara penyelesaian. Ada rasa senang, ketika saya menemukan jawaban yang benar dari soal, untuk soal nomor 8 sebaiknya gambar awan dialognya ada diatas agar bagus.

LEMBAR KOMENTAR SISWA

1. Terlalu sulit, soal seperti ini jarang diberikan oleh guru
2. Beberapa soal, kalimatnya sulit di pahami. Jadi tidak bisa mengerjakannya.
3. Dari 14 soal, hanya sebagian soal dapat di kerjakan

LEMBAR KOMENTAR SISWA

1. Soal yang diberikan sulit diselesaikan seperti nomor 12 dan 14
2. soalnya cukup menantang untuk dikerjakan
3. Membutuhkan pola pikir yang sedikit rumit untuk menyelesaikan soal
4. Karena sulit saya hanya bisa mengerjakan 70% saja
5. Soal yang paling menarik bagi saya adalah soal nomor 11 ~~dan~~ berbentuk permainan super mario menyelamatkan kucing dan nomor 13 yang ada kotak balok awannya.

LEMBAR KOMENTAR SISWA

1. Soalnya sangat kreatif, jarang ditemukan dilatihan-latihan atau bimbingan belajar.
2. Soalnya menantang, memerlukan pemikiran lebih untuk menyelesaikan soal yang ada.
3. Beberapa soal terlihat menarik dengan adanya gambar-gambar yang lucu.
4. Untuk gambar ~~nomor~~ pada soal nomor 10 sebaiknya diletakkan sebelum atau setelah ~~kalimat soal~~ kalimat soal.
5. Sedikit bingung dengan soal nomor 14, ~~orang~~ yang menggunakan segitiga samakaki namun gambarnya seperti segitiga siku-siku.
6. Karena soal-soal yang kreatif, saya lasa menggunakan cara saya sendiri untuk menyelesaikannya.

LEMBAR KOMENTAR SISWA

Menurut saya,
1. Cerita soalnya menarik dan lucu
2. Meski sulit, tetapi soal-soal ini menarik untuk dikerjakan, penasaran untuk mencari jawabannya
3. Menurut saya soal yang bagus dan jarang ditemui adalah soal nomor 9, 11 dan 13
4. Namun untuk nomor 13 gambar awannya sebaiknya diatas agar terlihat bagus
5. Soal nomor 9, kalimat soalnya lebih diperjelas lagi apa maksudnya
6. Saya tidak bisa mengerjakan sebagian saya

Figure 2. Small-Group Student Comments

In addition, students have also been given a question readability questionnaire. This is to determine the level of readability of the questions being developed.

Table 5. Question Readability Questionnaire Results

Respondents	Total score
1	36
2	34
3	35
4	32
5	34
Total	171
Average	34.5

Source: data analysis

Based on this table, the number of data obtained is 171. While the ideal score = 4 x 10 x 5 = 200. Thus the readability level of HOTS math problems in class X based on Krulik & Rudnick's overall = 171/200 = 0.855 is about 85.5% of the expected. So the HOTS class X math problems based on Krulik & Rudnick's development can be categorized as legible. Based on the comments and readability of the questions, it is said that the resulting hots questions are practical to be used to measure higher-order thinking skills. This is in line with the research conducted (Lewy; Zulkardi; Nyimas Aisyah, 2019), which states that the practicality of a problem is seen from the results of the trial.

Field Test

Table 6. Validity Test Results

Item Questions	$R_{\text{item v.s. total}}$	$sign < 0.05$	Validity
1	.553**	.000	Valid
2	.864**	.000	Valid
3	.598**	.000	Valid
4	.710*	.000	Valid
5	.474**	.003	Valid
6	.652**	.000	Valid
7	.845**	.000	Valid
8	.200	.243	Invalid
9	908**	.000	Valid
10	-.056	.745	Invalid
11	.871**	.000	Valid
12	.324	.054	Invalid
13	.886**	.000	Valid
14	781**	000	Valid

Source: data analysis

As for the level of difficulty and distinguishing power for prototype three, which was tested at the field test stage, each item obtained the following results:

Table 7. Test Results of Level of Difficulty and Distinguishing Power

No. question	Level of Difficulty	Distinguishing power	Decision
1	medium	Good	accepted
2	medium	Very good	accepted
3	medium	Good	accepted
4	medium	Very good	accepted
5	medium	Pretty good	accepted
6	medium	Good	accepted
7	medium	Very good	accepted
8	difficult	Ugly	rejected
9	medium	Very good	accepted
10	easy	Ugly	rejected
11	medium	Very good	accepted
12	medium	Ugly	rejected
13	difficult	Very good	accepted
14	difficult	Very good	accepted

Source: data analysis

Based on table 6, the results of the validity test and table 7 of the test results for the level of difficulty and distinguishing power of questions, questions 8, 10, and 12 are aborted. This shows that 11 items of class X HOTS math problems based on Krulik & Rudnick have been produced, which are valid and reliable. In line with the findings of Arifin and Retnawati (2017), which produced an instrument to measure students' higher-order thinking skills (Zaenal Arifin & Retnawati, 2017).

Table 8. Reliability Test Results

Reliability Statistics	
Cronbach's Alpha	N of Items
.921	11

The reliability of 0.921 is in the very high category (Widana, 2017a).

In addition to producing valid and reliable HOTS grade X math problems based on Krulik & Rudnick, this question must also be able to measure students' higher-order thinking skills. The following is the distribution of the average score of students' higher-order thinking skills.

Table 8. Distribution of Average High-Level Thinking Ability Score

Interval	Frekuensi	Persentase(%)	Kategori
49.6 – 66	4	11	Very good
33.1 – 49.5	14	39	Good
16.6 – 33	13	36	Pretty good
0 – 16.5	5	14	Not good
Jumlah	36	100	
Skor rata-rata		33,17	Baik

Source: data analysis

Based on the results of the analysis of students 'high-order thinking skills, in general, students' high-order thinking skills are categorized into four levels; namely, four students (11%) are very good, 14 students (39%) are good, 13 students (36%) are pretty good, and five students (14%) were not good. This matter shows that the questions that have been made/developed can measure the various high-order thinking skills of high school students, especially class X. This is in line with the opinion of Rahmawatiningrum et al. (2019) that HOTS questions can measure students' skills at various levels of high-order thinking skills (Rahmawatiningrum et al., 2019). The results of the analysis also show that the average high-order thinking skills of students are in a good category. This is in line with the findings of Kurniati et al. (2016) that the high-level thinking abilities of junior high school students are at medium and low levels (Kurniati, Harimukti, & Jamil, 2016). Megawati et al. (2019) also reported that the high-level thinking skills of junior high school students were lacking, especially in evaluating skills (Megawati, Wardani, & Hartatiana, 2019). This matter shows that there is still a great need for further efforts by the teacher so that they can share questions that can spur a variety of high-level thinking skills of students, especially high school-level HOTS questions. Valid, reliable, and practical questions obtained from this research can be used by teachers in the teaching and learning process in the classroom.

If you look at the distribution of each indicator of high-order thinking skills, namely critical and creative thinking skills, it can be seen in the following diagram.

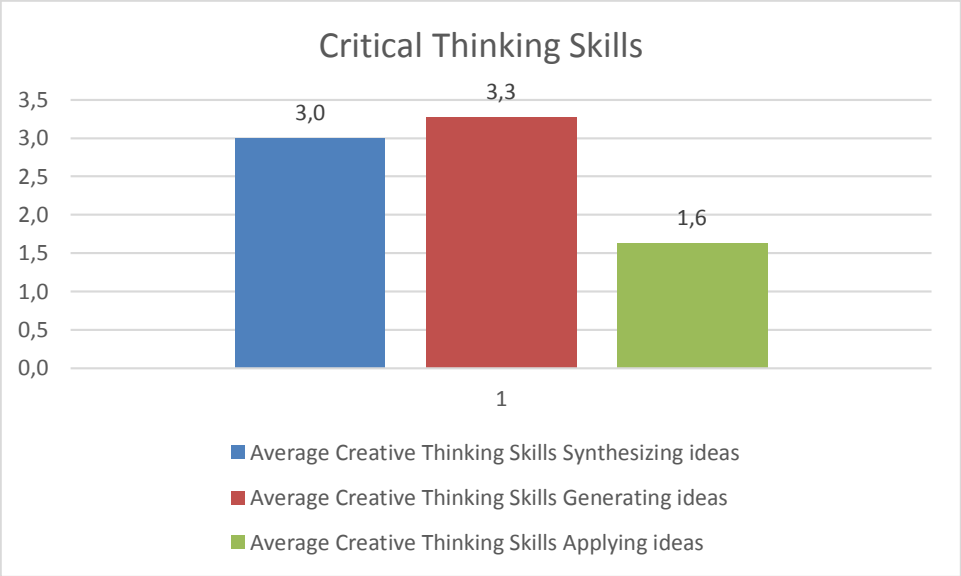


Diagram 2. Distribution of Krulik & Rudnik's Critical Thinking Skills

It can be seen that the student's critical thinking skills are in the good category with the smallest average score, namely analysis skills 3.1, and the highest average score for associating skills is 3.7.

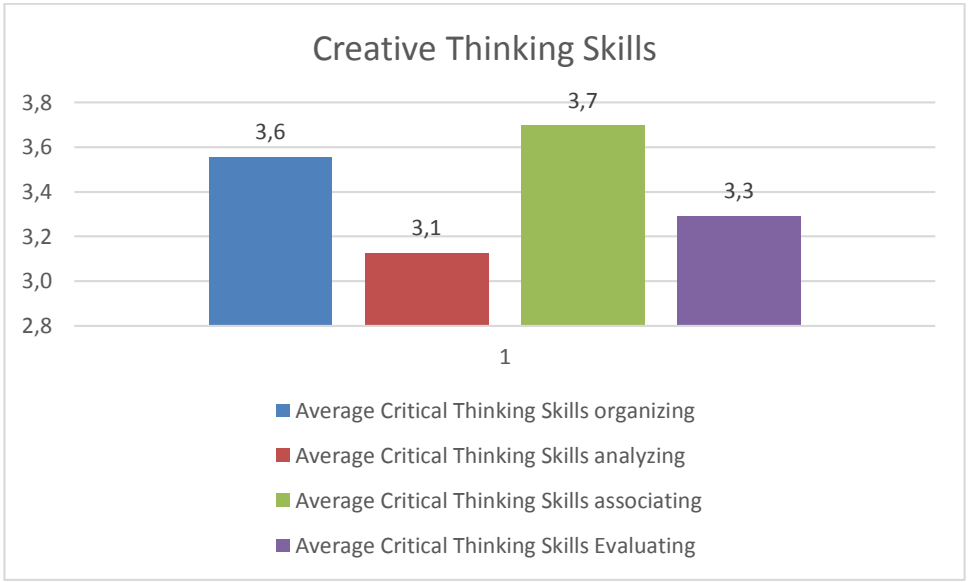


Diagram 3. Distribution of Krulik & Rudnik's Creative Thinking Skills

It can be seen that the student's creative thinking skills lie in the fairly good category with the smallest average score, namely the skills to apply ideas of 1.6, and the highest average score of idea building skills is 3.3. From these two indicators of critical and creative thinking skills, Krulik & Rudnik, creative thinking skills need special attention to be improved.

Mathematical HOTS questions are essential to developing because there are still only a few HOTS questions (Johar et al., 2018; Prasetya, 2017). HOTS questions can also improve students' knowledge and skills (T. Widodo & Kadarwati, 2013). Students who are accustomed to answering HOTS questions will have high-order thinking skills that will help them achieve

academic achievement (Conklin, 2011) and the demands of the 21st century (Brookhart, 2010; Collins, 2014; Forehand, 2010; Widana, 2017b). Following Listiani and Prihatnani's (2018) opinion that learning innovation is needed to improve higher-order thinking skills (Listiani & Prihatnani, 2018).

CONCLUSION

Based on the results of data analysis, a prototype of the HOTS question set by Krulik & Rudnick has been produced, which consists of 11 items developed that are valid, practical, and reliable, declared valid for each item because, in addition, 11 items produced were valid with sign <0.05. The prototype set of questions developed was categorized as reliable. The correlation value of Cronbach's Alpha was 0.921.

In addition, the HOTS math problem class X ala Krulik & Rudnick developed was also able to measure the high-order thinking skills of class X MIPA E students at SMA Negeri 1 Kediri with an average score of 33.17 from a maximum score of 66 where this value includes having the ability high-level thinking is good.

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