Measuring Construct Validity and Students' Mathematical Creative Thinking Skills

Kadir[1] and Irna Rahmawati[1]
[1]*Department of Mathematics Education, Universitas Islam Negeri Syarif Hidayatullah Jakarta*

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Abstract: This study aims to measure construct validity tests of mathematical creative thinking skills (MCTS) and analyze students' MCTS. This research was conducted at a Junior High Schools in the city of Bekasi. This study was a survey involving 180 students as participants. Data analysis uses confirmatory factor analysis (CFA) and path analysis. The results revealed that: (1) Tests of MCTS are valid and consistently measured through fluency, elaboration, flexibility, and originality constructs; (2) Construct reliability of the fluency indicator is 0.952, elaboration of 0.976, flexibility of 0.622, and originality of 0.710; (3) Overall the average student's MCTS is 50.27 on a scale (0-100), where female students are 61.45 and male is 49.54. Achievement the highest MCTS of students is obtained in the flexibility indicator of 68.08 then the fluency is 66.95, elaboration is 34.30, and the lowest is the originality indicator 31.76; (4) Students' MCTS on the fluency indicator has an indirect effect on the indicator of originality through moderating indicators of elaboration and flexibility. The conclusion of this study is that MCTS are measured from indicators of fluency, elaboration, flexibility, and originality. The overall MCTS of students is still relatively low, where female students are quite good and higher than male students. The ability to solve problems in the originality indicator is the core of MCTS.

1 INTRODUCTION

The intellectual factor needed to develop competitiveness in the industrial revolution era 4.0 is the ability to think creatively. It is included in the category of high-level thinking skills (HOTs). Educational institutions are the most conducive place to develop curricula that can produce creative and competitive graduates. (Saini, 2015), argued that the development of the 2013 curriculum, strives to improve the quality of education to produce graduates who are creative and able to face future challenges. The development and formation of individual creativity potential must be integrated in the curriculum content. Furthermore, (Sternbergn, 2001) and (Sternbergn & Lubart, 2000) suggested that individual creative potential will be latent if not developed and formed.

Mathematics as part of the curriculum plays an important role in fostering students to have creative thinking skills. It is a way or method of thinking and is taught to build the mindset. Moreover, reasoning of students in solving problems critically, logically and precisely.

The vision of learning mathematics are: (1) directing understanding of mathematical concepts and ideas needed to solve mathematical and other scientific problems, (2) providing opportunities for developing logical, systematic, critical and careful, creative reasoning abilities , fostering self-confidence, and a sense of beauty towards the nature of mathematics (Hendriana & Sumarmo, 2014).

Mathematical creativity is defined as a framework of mathematical knowledge is the ability to solve problems or to develop thinking in a structure, taking into account the logic-deductive nature that is typical of the discipline, and the concepts produced. Because the definition is related to originality and usability, the definition of mathematics (Kadir, Lucyana, & Satriawati, 2017).

Mathematical creativity at a professional level, defined as: 1) The ability to produce original works that significantly expand the body of knowledge; 2) The ability to open new questions for other mathematicians; 3) Processes that produce unusual and profound solutions to given problems or analog problems; 4) Formulation of questions and / or new

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possibilities that allow old problems to be considered from a new perspective (Sriraman, 2005)

Creative thinking includes aspects of cognitive, affective, and metacognitive skills. The aspect of cognitive skills contains the ability: identify problems, compose different questions, identify relevant and irrelevant data, generate many ideas (fluency), different ideas (flexibility), new ideas, change old mindsets and habits, compose new relationships and renew plans or ideas (Siswono, 2008). The characteristics of creative thinking abilities, includes: 1) Fluency, namely the ability to produce many ideas, solve problems or questions; 2) Flexibility, namely the ability to produce many varied and different ways; 3) Originality, namely the ability to think in new ways or with unique expressions and unusual thoughts from thoughts that are clearly known; 4) Elaboration, namely the ability to detail an object, idea, or situation (Siswono, 2008). Based on this definition, it can be concluded that the ability to think creatively in mathematics learning which later became known as mathematical creative thinking skills (MCTS) is an ability that reflects fluency, flexibility, and originality in thinking, as well as the ability to elaborate an idea in solving mathematical problems. Thus, the indicator of MCTS are fluency, elaboration, flexibility, and originality.

But in reality, MCTS Indonesian students have not been reached maximally. The results of an international study of the 2015, Program for International Student Assessment (PISA) showed that only about 10% of Indonesian students were able to answer level 4, 5, and 6 tests. Characteristics of tests at level 4, 5, and 6, contained questions which requires the ability to construct, express explanations and compile arguments based on interpretation. Work in complex situations, identify constraints, choose, compare, and evaluate problem solving strategies, use broad reasoning, reflect, formulate and express interpretations and reasoning. Think of high-level mathematics and put it right about their findings, arguments, and accuracy in the original situation (PISA, 2015). Furthermore, the results of Fardah's research revealed that the achievement of MCTS of elementary and secondary school students is still in the low category, which is 46.67% (Fardah, 2012).

Some of the efforts to improve students' MCTS, are in providing learning interventions through work on non-routine problem tests. Learning evaluations that involve students in completing non-routine tests must be presented in class. According to Novita et al., (Novita, Zulkardi, & Hartono, 2012) that one of the factors causing low scores obtained by students on the PISA test is the test material and international standardized test from PISA not yet taught in class. Besides that most tests in the evaluation process are still at a low level. Therefore, the mathematical problem solving test formulated in PISA can be adapted to develop MCTS tests.

Several recent studies in Indonesia are related to the development of students' MCTS instruments (Fitriani & Yarmayani, 2018) (Fitriani & Yarmayani, 2018) (Fitriarosah, 2016) (Moma, 2015). Generally this research is a development research with validity analysis, reliability, discriminating index, and item difficulty level. The study has not developed and measured the construct through the Confirmatory Factor Analysis procedure. Almost no research has specifically explained the theoretical constructs of the MCTS test empirically. Therefore, this study aims to: (1) measure the construct validity of MCTS tests, and (2) analyze students' MCTS.

2 METHOD

This study was a survey conducted in 6 junior high schools (SMP A, SMP B, SMP C, SMP D, SMP E and SMP F) in the city of Bekasi involving 180 students (male = 98, female = 82) as participants. A total of 30 students were taken randomly from each school. The MCTS test developed in the form of an essay consists of 11 items, representing fluency indicators, elaboration, flexibility, and originality. Representation of items into indicators, including: fluency (1, 2, 3), elaboration (4, 5), flexibility (6, 7, 8), and originality (9, 10, 11). This study involves rectangular flat geometry. Before empirically testing MCTS test items, it was first assessed the feasibility of expert panelists from the aspect of content and the accuracy of items measuring indicators. Furthermore, an assessment of student answers from the MCTS test results uses a rubric adapted from Bosch (Bosch, 2008). The rubrics of students' creative mathematical thinking skills, in Table 1.

Table 1: Rubric of the MCTS Test

Indicator	Score	Descriptors
Fluency	0	No answer or no relevant answer
	1	Give an idea that is relevant to problem solving but the disclosure is less clear or wrong.
	2	Provide an idea that is relevant to problem solving but the

		completion and disclosure is incomplete or unclear.
	3	Provide more than one idea/answer that is relevant to solving the problem but the solution is unclear.
	4	Provide more than one idea/answer that is relevant to problem solving and full and clear disclosure.
Elaboration	0	Don't answer or give the wrong answer.
	1	There is a mistake in expanding the situation without details.
	2	There is a mistake in expanding the situation and still not detailed.
	3	Extending the situation correctly but not detailed.
	4	Expand the situation correctly and in detail.
Flexibility	0	Do not answer or give answers in one way or more but everything is wrong.
	1	Give answers in only one way, there are errors in the calculation process, that the results are wrong.
	2	Give answers in one way, the calculation process and the results are correct.
	3	Give answers in more than one way (various) but the results are wrong because there is a mistake in the calculation process.
	4	Give answers in more than one way (various), the calculation process of the results is correct.
Originality	0	Do not give answers or give wrong answers.
	1	Give answers in their own way but cannot be understood.
	2	Providing an answer in its own way, the calculation process is directed but not completed.
	3	Give answers in their own way but the results are wrong because there is a mistake in the calculation process.
	4	Give answers in their own way, the calculation process and the results are correct.

The data analysis technique uses Confirmatory Factor Analysis (CFA) with Lisrel 88.00 and AMOS version 20. CFA analysis techniques use SEM (Structural Equation Modeling) with a measurement model. Item validity is determined based on the loading factor test. Empirically an indicator or item is said to be valid measuring construct if the estimation results of loading factor (λ) > 0.5 or has a t-test statistical value with a p-value < 0.05.

An indicator is said to be dominant if it has $\lambda^2 \geq 0.70$ (Hair, Black, Babin, & Anderson, 2010). Determination of Composite Reliability is based on a composite internal consistency of construct measurement indicators. In general a construct, unidimensional, precise, and consistent can be measured by indicators / items, if: (a) the model is fit with the data, (b) Loading factor (λ) is significant above 1.96 or (λ) > 0.50 and (c) Estimation of the coefficient of *CR* (Composite Reliability) ≥ 0.70 and *VE* (Variance Extracted) ≥ 0.50 (Hair et al., 2010).

The Construct Reliability (*CR*) and Variance Extracted (*VE*) formulas are as follows:

$$CR_i = \frac{\left(\sum_{i=1}^{k}\lambda_i\right)^2}{\left(\sum_{i=1}^{k}\lambda_i\right)^2 + \left(\sum_{i=1}^{k}\theta_i\right)} \quad \text{and} \quad VE_i = \frac{\left(\sum_{i=1}^{k}\lambda_i\right)^2}{k}, \text{ w}$$

here:

λ_i = loading indicator factor to - i,

θ_i = indicator variance error to – i

k = number of indicators in the model

3 RESULTS AND DISCUSSION

CFA analysis technique aims to estimate the accuracy of the items that measure factors that have been compiled based on theoretical constructs. Through CFA analysis, the construct estimates are: (1) fluency, (2) elaboration, (3) flexibility, and (4) originality.

3.1 Construct Validity

The results of estimation of loading factor in Table 2.

Table 2: Results of estimated loading factor with CFA

Factors	No	*Loading Factor*	$t_{observe}$	t_{table}	Decision
Fluency	1	0.986	18.408	1.96	Sig
	2	0.961	17.409	1.96	Sig
	3	0.978	18.135	1.96	Sig
Elaboration	4	0.986	17.571	1.96	Sig
	5	0.990	17.681	1.96	Sig
Flexibility	6	0.277	2.108	1.96	Sig
	7	0.359	2.270	1.96	Sig
	8	0.065	0.576	1.96	Non Sig
Originality	9	0.713	7.527	1.96	Sig
	10	0.319	3.616	1.96	Sig
	11	0.473	5.449	1.96	Sig

Based on the results of the analysis in Table 2, it shows that all items except item number 8, have t-observe > t-table = 1.96. This means that all items of MCTS except item number 8 are declared valid measuring constructs of fluency, elaboration, flexibility, and originality. Thus, the MCTS consisted of 10 items (valid) and four indicators, namely fluency consisting of 3 items with loading factors (0.986; 0.961; 0.978), elaboration consisting of 2 items with loading factors (0.986; 0.990), flexibility consisting of 2 items with loading factors (0.277; 0.359) and originality consisted of 3 items with loading factors (0.713; 0.319; 0.473). The findings of this study, in contrast to the findings of (Fitriarosah, 2016) about the MCTS, found a set of MCTS test consisting of 4 valid items, the reliability of good categories, also had a good discriminating index and varying degrees of difficulty.

Visually loading factors from the MCTS test are presented in the path diagram in Figure 1.

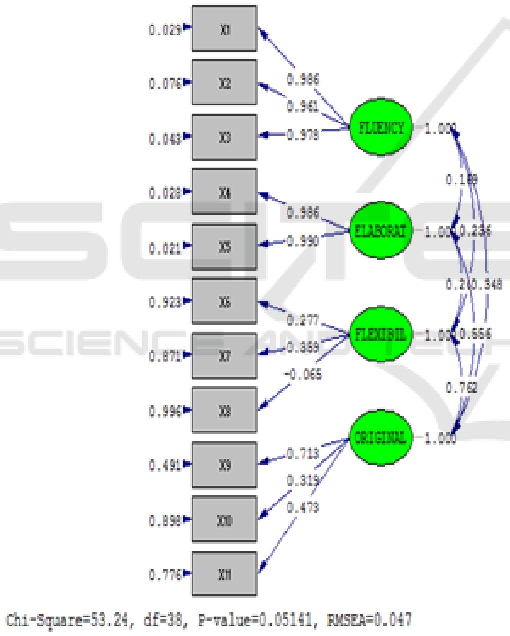


Figure 1: Path Diagram of Loading Factor

The path diagram of the factor loading estimation results from the MCTS test with the t-test is presented in Figure 2.

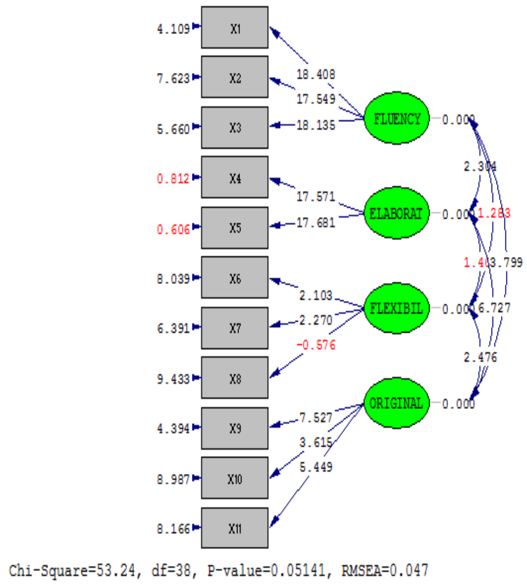


Figure 2: Path Diagram of the Loading Factor with the t-test

3.2 Reliability

The reliability estimation results from the MCTS test are presented in Table 3.

Table 3: Results of MCTS test reliability estimates

Factor	Number of items	Construct Reliability	Varians Extracted
Fluency	3	0.952	0.952
Elaboration	2	0.976	0.976
Flexibility	2	0.622	0.503
Originality	2	0.710	0.578
Total	10	0.815	0.752

From the results of the analysis in Table 3, the overall CR value is 0.815 and VE is 0.752. By using criteria from estimates for CR $\geq$ 0.70 and VE $\geq$ 0.50, this finding reveals that the construct of the test, right, and consistently measuring MCTS or having internal consistency is good (Hair et al., 2010). This finding is similar to La Moma's finding that the MCTS test reliability is 0.840 but uses the Cronbach Alpha formula (Moma, 2015).

3.3 Test of Goodness of Fit Statistics

Testing fit models aimed at studying how precise the measurement model proposed can fit the research data. The results of the analysis relating to the size of the model Fit, are presented in Table 4.

Table 4: Summary of fit model indication

Goodness of Fit	Fit Indicators	Result	Judge
Chi-Square (p)	p > 0.05	p = 0.051	fulfilled
RMSEA	< 0.05	0.047	fulfilled

The analysis in Table 4, shows that indicators Goodness of Fit were fulfilled. This means that the conceptual model of the proposed MCTS test is fit with the data.

3.4 Mathematical Creative Thinking Skill (MCTS)

Students' overall mathematical creative thinking skills (MCTS) are presented in Table 5.

Table 5: Descriptive statistics of students' MCTS

N	Valid	180
	Missing	0
Mean		50.27
Median		48.00
Mode		48
Std. Deviation		10.272
Variance		105.524
Skewness		.525
Std. Error of Skewness		.181
Kurtosis		.206
Std. Error of Kurtosis		.360
Range		48
Minimum		30
Maximum		78

It can be seen from Table 5, as a whole from 180 students as respondents, indicating that students' mathematical creative thinking skills are still low in level.

Visually the distribution of students' MCTS data, as a whole is presented in Figure 3. Based on Figure 3, it is found that the MCTS data distribution has a tendency to collect below the empirical average.

This means that the MCTS data distribution is grouped below the average. Thus the ability of MCTS students is still relatively low.

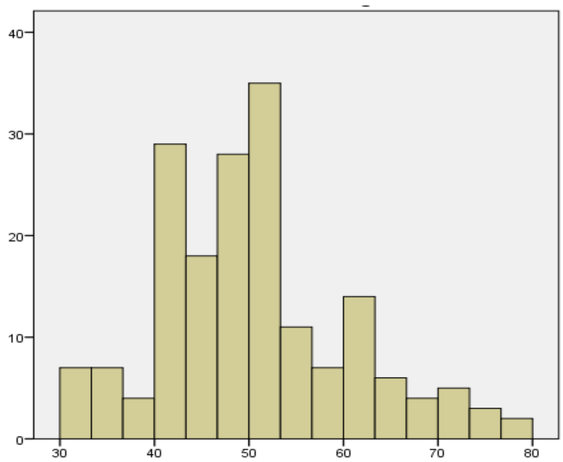


Figure 3: Frequency Histogram of students' MCTS as a whole

Students' MCTS data by gender score in Table 6.

Table 6: Data on sudents' MCTS

Statistics	Mathematical Creative Thinking Skills (MCTS)		
	Male	Female	Total
N	98	82	180
Std. Deviation	1274	13.32	10.27
Mean	49.54	61.45	50.27
Median	48.75	49.88	48.00
Modus	50.83	52.50	48.00
Minimum	33	45	30
Maximum	70	83	78

The results of the analysis in Table 6, show that from 180 students as respondents, an average score of 50.27, a maximum value of 78 and a minimum of 30, a median of 48.00, Mode 48, and Std. Deviation 10.27. This finding reveals that the ability of students' MCTS is still relatively low.

The findings of this study, similar to the research of (Fitriani & Yarmayani, 2018) who developed the MCTS rubric of students of Senior High School, found that the classification of highly creative abilities (75-96) was 0%, creative (50-74) as much as 39.13 %, quite creative (25-49) of 60.86%, and less creative (0-24) as much as 0% [12]. From Table IV, also obtained the average MCTS score of male students was 49.54 and female was 61.45. This means that MCTS female students are higher than male students. The findings of this study are in accordance with the opinion of Krutestkii (Nafi'an, 2011), explaining that men are superior in reasoning, women are superior in precision, accuracy, and more careful in thinking. Men have better mathematical and mechanical abilities than women, this difference is not apparent at the basic level but becomes more apparent at a higher level.

Furthermore, student scores on each indicator from MCTS based on the school in the Table 7.

Table 7: average student scores for each MCTS indicator and school

School	N	Average students' MCTS for each indicator				Mean
		Fluency	Elabor	Flexi	Origin	
A	30	71.17	42.70	64.33	29.93	52.03
B	30	61.90	29.30	69.83	24.70	46.43
C	30	70.17	30.60	69.03	33.27	50.77
D	30	75.90	48.63	83.60	52.50	65.16
E	30	63.00	26.93	63.57	26.63	45.03
F	30	59.53	27.63	58.13	23.50	42.20
Mean	180	66.95	34.30	68.08	31,76	**50.27**

Based on the results of the analysis in Table 7, the students' ability score on the fluency indicator is 66.95, elaboration is 34.30, flexibility is 68.08 and originality is 31.76. Research findings confirm that flexibility is an indicator that is better than fluency, elaboration, and originality. The fluency indicator is the ability to provide many answers, then the elaboration indicator, namely the ability to write information that is known to the problem. While the flexibility indicator is the ability to provide alternative ways to solve problems, and the originality indicator is to produce unusual or unique answers according to quadrilateral geometry. The findings of this study are somewhat different from the findings of (Fatimatuzahro & M Budiarto, 2014), who reported that students with high mathematical abilities had better creative thinking skills on indicators of fluency and elaboration, while students with moderate math ability were only better at fluency indicators and students with low abilities did not show creative thinking skills.

3.5 Test the Influence Hypothesis among the MCTS Indicators

Hypothesis test results of the influence between the MCTS indicators in Table 8.

Table 7: Results of influence among the MCTS indicators

Influence among indicator	Est	S.E.	C.R.	p
Elaboration ← Fluency	.235	.054	3.234	**.001**
Flexibility ← Fluency	.053	.070	.700	.484
Flexibility ← Elaboration	.166	.093	2.201	**.028**
Originality ← Flexibility	.200	.074	2.708	**.007**
Originality ← Elaboration	.052	.094	.689	.491
Originality ← Fluency	.080	.069	1.068	.285

Based on the analysis results in Table 8, it shows that the indicators: (1) fluency has an influence on the elaboration indicator (p = 0.001 <0.05); (2) fluency has an influence on flexibility (p = 0.484> 0.05); (3) elaboration has an influence on flexibility (p = 0.028 <0.05); (4) flexibility has an influence on originality (p = 0.007 <0.05); (5) elaboration has no effect on originality (p = 0.491> 0.05); (6) fluency does not have an influence on the originality indicator (p = 0.285> 0.05). Thus the hierarchy of influence according to the MCTS indicator starts from the lowest position of fluency, elaboration, flexibility and the highest position on originality.

Visually the relationship between MCTS items and indicators in Figure 4.

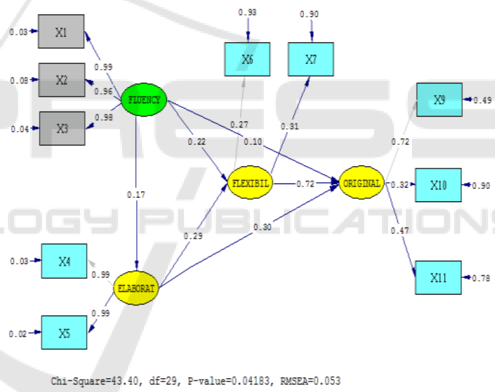


Figure 4: Relationship between test items and indicators

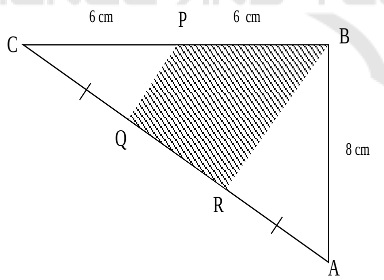
The research findings revealed that the students' MCTS on the fluency indicator had a positive effect on students' ability on the elaboration indicator. Thus the higher the ability of students in the fluency indicator, the higher the ability of students in elaboration skills. This finding shows that the ability to provide many ideas in determining the area and circumference of the rectangle supports the students' ability to enrich the detailed information of rectangular Geometry problems. While the ability of students on the elaboration indicator has a positive effect on students' ability in flexibility. This means that the ability of students on the elaboration indicator determines students' abilities on flexibility indicators. Thus the higher the student's ability in the elaboration indicator, the higher the student's ability in flexibility. This finding confirms that students' ability to detail details of information or data from a rectangular flat geometry problem helps students make several different interpretations in solving rectangular-related problems.

Furthermore, the ability of students on the flexibility indicator has a positive effect on students' abilities in the originality indicator. This means that the ability of students on the flexibility indicator can actually explain students' abilities in the originality indicator. This finding describes that the ability to produce ideas, answers or questions that vary, can see problems from different points of view, and are able to find many alternatives or different directions from the problem of rectangular geometry to a capacity to express new and unique things, thinking of unusual ways, and making unusual combinations of rectangular elements.

The findings of this study also provide a distinctive and novelty related to the MCTS test measuring indicator, namely that through path analysis between indicators, we find a hierarchy of abilities as a sequence of abilities that starts from the fluency indicator then elaboration, flexibility and ends in the originality indicator as the highest ability in creative thinking.

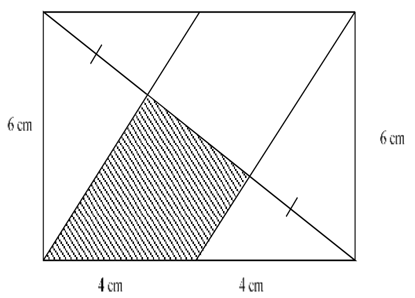
The following are examples of questions and student answers to the originality indicator.

"Pay attention to the right triangle below. The BR line is parallel to the PQ line with point P as the midpoint of the BC line. Determine the area to be shaded? "



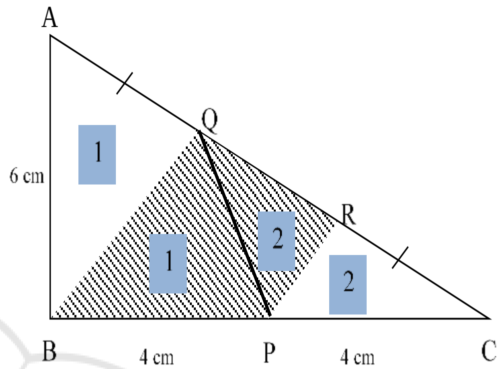
Students' answers to the questions above are made in two ways, namely:

<u>Answer 1:</u>
By constructing the flat trapezium into a rectangle and parallelogram.



From this picture the area of shading = 1/2 the area of parallelogram, while area of parallelogram = area of rectangular area - 2 area of triangle.
Area of parallelogram = (6 x 8) –2 (½(4 x 6)) = 48 – 24 = 24 cm^2. Dhus area of shading = 1/2 area of parallelogram = ½ x 24 = 12 cm^2

<u>Answer 2:</u>
Draw a line from one of the trapezium points to another.



It is seen that the area of the trapezium is formed of several triangles. Dhus area of shading = 1/2 the area of ABC right triangle = ½ x ½ (6 x 8) = ¼ x 48 = 12 cm^2.

Thus the core of MCTS is developing the ability to focus on the originality indicators. As with Sriraman's definition, that mathematical creativity is the ability to produce original works that significantly extends the body of knowledge (Sriraman, 2005). To maximize MCTS in the originality indicator, the flexibility capability is needed. While increasing flexibility is determined by fluency and elaboration abilities. This finding confirms that the role of fluency indicator capability on originality can be mediated by indicators of elaboration and flexibility. We believe that these findings are new findings that complement previous studies related to the ability to think creatively in mathematics learning.

4 CONCLUSION

Based on the findings and discussion, it can be concluded that the MCTS test is valid and consistently measured through constructs or indicators of fluency, elaboration, flexibility, and originality. Overall, the MCTS test construct has an internal consistency of 0.815 or a very good category. MCTS test consists of 10 items and four indicators, namely fluency consisting of 3 items with loading factors (0, 986; 0.961; 0.978) and construct reliability of 0.952; elaboration consists of 2 items with loading factors (0.986; 0.990) and construct reliability of 0.976, Flexibility consists of 2 items with loading factors (0.277; 0.359) and construct reliability of 0.622, and originality consists of 3 items with loading factors (0.713; 0.319; 0.473) and construct reliability of 0.710.

The overall MCTS of students is still relatively low, which is an average of 50.27 on a scale (0-100). Achievement the highest MCTS of students is obtained in the flexibility indicator of 68.08; then the fluency is 66.95, elaboration is 34.30, and the lowest is the originality indicator 31.76. The average MCTS of female students is 61.45 and male students are 49.54. Thus, MCTS of female students are quite good and higher than male students. The influence of ability on the fluency indicator on originality is mediated by indicators of elaboration and flexibility. The ability to solve problems in the originality indicator is the core of students' creative thinking ability. Therefore, it is suggested that to improve students' creative thinking skills students should begin gradually from problems that measure fluency indicator abilities then elaboration, flexibility and end with originality. To maximize students' ability to think creatively mathematically on the originality indicator, the best performance is needed on the flexibility indicator. While increasing flexibility is determined by fluency and elaboration abilities.

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