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Students' Performance on Mathematical Creative Thinking-based Ethnomathematics: A Rasch Measurement

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Abstract. This study aimed to investigate the item difficulty patterns, the validity and reliability factors, as the diagnostic development-based ethnomathematics of students' mathematical creative thinking (MCT), and to evaluate the students' performance. A total of 186 Indonesian secondary school students were randomly selected to participate. Rasch measurement and descriptive statistics were incorporated into the statistical analysis using SPSS and Winstep. To assess the extent to which objects and people interact, all data sets were studied. We found that the dependability of the designed test items exceeded 0.77 for persons and 0.99 for items. In the differences test, there were no DIF. This result demonstrates no difference between girls and boys in the distribution of MCT dimension scores. The established diagnostic test and practical analysis based on Rasch measurements are anticipated to serve as guidance and suggestions for other researchers engaged in developing MCT-based ethnomathematics research.

INTRODUCTION

This educational demonstration emphasizes the value of creativity. Understanding how the creativity of pupils is to be evaluated and how it is to be implemented in works would enhance the teaching of creativity. Creativity exists in all human endeavors, disciplines, and occupations. Creativity and innovation are important for ensuring Indonesia's sustainable development [1]. According to Cropley [2], creativity is frequently portrayed as a fascinating and even supernatural process, resembling divine inspiration more than mundane thought. With creativity, a person can effectively express the fruits of his imagination. Thus, creativity is frequently considered one of the most mysterious topics in cognitive psychology. According to a number of studies [3], intelligence and creativity are distinct constructs; that is, a highly intelligent individual may or may not also be highly creative. In the past several decades, a growing interest in creativity has been accompanied by a search for appropriate evaluation tools, which has resulted in the development of creativity tests, particularly those meant to measure children's creative potential [4]. Torrance [5] proposed that testing is a valid method for discovering the nature of creativity. Additionally, creativity assessments can identify a child's skills and shortcomings [6]. Therefore, creativity tests are essential for measuring creative abilities [7], understanding creativity, and possibly contributing to the cognitive development of individuals [8].

NCTM 2022 indicates that in order to prepare for the 21st century, today's students should be able to employ mathematical knowledge to solve problems, communicate mathematically, think mathematically, and demonstrate mathematical abilities. It also emphasizes that pupils must be presented with challenging problems that will encourage them to build diversified and solid mathematical thought processes and to think creatively. In mathematics, "open-ended" or "open-response" problems and questions that demand more than one answer can be used to assess the ability to think creatively and to communicate effectively.

Students are required to possess MCT, which is typically based on an underlying process or a manifested product. On the basis of the framework of the 21st century, creativity can aid students' quickly evolving global competencies. In light of this, educational research should incorporate tests for measuring MCT proficiency. The

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importance of MCT assessment in the classroom and the significance of MCT for students. According to the Programme for International Student Assessment (PISA), MCT is the ability to engage in constructive learning, evaluation, and improvement of ideas that can lead to innovative, practical solutions [9]. In other words, mathematical concepts are abstract representations of everyday activities (school). The Indonensia National Examination in 2019 showed that the matheematics score were 46.56 out of mean score valuee of 100 [10]. Even the Indonesian curriculum (K-13) addressed that the primary objective is to develop critical, creative, and innovative skills. Then in the new curriculum for independent curriculum, we called "Merdeka Belajar". The Independent Learning Curriculum is the outcome and implementation of a crisis educational program launched to counter the effects of the Covid-19 pandemic [11]. In this curriculum perspective, the teacher should be more independent to teach with school culture and develop assessment tests to identify mathematical performance.

However, mathematical achievement in secondary school has not increased from year to year. Based on the PISA 2018 test results, Indonesia still ranks low for the results of mathematics tests which are ranked 73 for mathematics from 79 countries [12]. The phenomenon is a lack of condition and should be tackled in mathematics assessment. These results highlight the need and importance of improving the MCT assessment in Indonesia.

Some Indonesian researchers, e.g., Rahayuningsih [13] reported examining the mathematical creativity profile of pupils using an open-ended problem-solving and interview assessment instrument. Unfortunately, the test to assess creative thinking does not provide an explanation of its validity and reliability and remains a simple routine task. Furthermore, Richardo & Martyanti [14] reported developing an ethnomathematical test, but this test measures critical thinking ability and does not report psychometrics. Another research comes from Ogunkenle & George [15] that they have integrated of an ethnomathematical into secondary mathematics school to measure creative thinking skills. Unfortunately, the limitation were the questionnaire type. Additionally, Sumarni & Kadarwati [16] research found that 230 students from seven high schools in Central Java, Indonesia, were observed by creative thinking tools. Nevertheless, the instrument doesn't cover the model fit validity and remains a regular task and the questions remain routine. It was because credible and standardized tests were limited for identifying pupils with creative thinking abilities in ethnomathematics content. As a systematic review report, the creative thinking in mathematics can be assessed with open-ended ethnomathematics [17]. Ethnomathematics is the study of mathematics using a cultural approach. Based on the logical theory, how is MCT to be assessed using the diagnostic test of MCT development-based ethnomathematics? Furthermore,

RQ1: Does the data collected achieve reliability and validity from a sample of secondary students fit the Rasch model?
RQ2: How do the students' mathematical creative thinking performance in terms of school types?
RQ3: How do the evaluation of students' performance on MCTtBE across gender?

THEORETICAL BACKGROUND

Mathematical Creative Thinking

As part of this review of the current literature, it is useful to analyze a number of significant pieces of research in the context of creativity from a broad domain perspective. This will explain how creativity research has enabled mathematicians to discover linkages between domain-general creativity and domain-specific [mathematical] creativity [18]. To grasp the current state of mathematical creativity, one needs to be familiar with the basic contributions of an English professor and a French mathematician, Graham Wallas (1858-1932) and Henri Poincaré (1854-1912). During an enlightening presentation to the French Psychological Society, Poincaré established the foundation for mathematical creativity and "defined rather than described the values of mathematical creativity" [19]. In 1926, Wallas developed 4-stages model as a challanges work of Poincaré and known as Gestalt Model of Creativity. A brief descriptions of each stages were fistly, preparation (conscious) mans that a problem is throughly investigated, secondly is incubation (unconscious) its mean that the individu is not consciously thinkign about the problem but the mind way be unconsciously interacting with th idea. Thirdly, illumination (unconscious). This is an idea is revaled to be individul, usually abruptly and unexpectedly. Laslty is verification (conscious), in this view conscious and concrete proof to validate the illumination [20].

In the domain of mathematics, the Gestalt Model of Creativity is broadly accepted. Sriraman [21] did qualitative research in which he investigated mathematicians' mental processes and validated the application of the Gestalt Model. This investigation established the point at which incubation was replaced by illumination. Multiple mathematicians in the study mentioned how this insight came at important times. "Many claimed that the

breakthrough occurred when they were going to bed, strolling, or sometimes after discussing the issue with another person". Anothers research explained that there were relationship between mathematical ability and creatvity, also shwon to have a positive relationship [22–24] and high correltations [25]. Additionaly, studies reported that relationships between mathematical creativity and mathematical achievement have been primarily studied and demonstrated for secondary school students [26,27], thus suggesting conclusions regarding the relationship between mathematical ability and creativity.

Ethnomathematics

D'Ambrosio [28] popularized the term ethnomathematics to describe the mathematical practices of distinct ethnic groups; it can be considered as the study of mathematical concepts found in any culture. Moreover, ethnomathematics can be described as the study of how people from a certain culture utilize shared systems to manage quantitative, relational, and geographical aspects of their existence [29]. Therefore, it provides information regarding the social function of mathematics. Ethnomathematicians argue that the prevalent conception of mathematics as Eurocentric and value-free misrepresents the historical evolution of contemporary mathematics [30,31].

Current ethnomathematics studies are many and widely dispersed, making it difficult to acquire a global perspective on ethnomathematical research practices. We started with D'Ambrosio's approach to ethnomathematics as a philosophical framework for our ethnomathematical research. D'Ambrosio [32] coined the term ethnomathematics to describe an identifiable cultural group of mathematical practice and might be considered the study of mathematical ideas found in any culture. Furthermore, D'Ambrosio [32] defines ethnomathematics as: *"The prefix ethno is today accepted as an extensive term that refers to the social-cultural context, and therefore includes language, jargon, and codes of behavior, myths, and symbols. The derivation of mathema is difficult but tends to mean explaining, knowing, understanding, and doing activities such as ciphering, measuring, classifying, ordering, inferring, and modeling. The suffix tics is derived from techne, and has the same root as art and technique".*

Several researchers conducted the ethnomathematics issue as a research activity, Gerdes in his early paper (1981, 1985, 1986) and D'Ambrosio regularly and explicitly writer on ethnomathematics [29]. However, these previous studies focus more on anthropological and political issues than on the mathematics education section. Although ethnomathematics was once regarded as a promising approach, many researchers have debated its position and perspective in education, particularly mathematics education.

Tapis Lampung: An Ethnomathematical Opportunity in Indonesia

Lampung is one province in Indonesia. One of the most well-known and most respected cultural items is Tapis [33]. Tapis is an item of Lampung women's clothing; a shaped sarong made from cotton yarn woven with a motif or decoration material sugi, silver thread or gold thread with embroidery [34]. Tapis Lampung is rich in mathematical concepts, making it suitable as an alternative assessing resource in mathematics testing, especially geometry material. In general, geometric decorations found on Tapis fabrics have firm contours using a variety of line elements, including straight lines, curves, zigzags, and spirals, as well as different shapes, including triangles and rectangles, circles, kites, regular polygons, and geometric transformations. Tapis Lampung may be used to develop assessing resources to teach mathematics related to ethnomathematics, geometrical, and other concepts.

METHOD

Participants

This study took place in the Lampung province of Indonesia. 186 Indonesian secondary school students (Girls = 115, Boys = 71; Mean age = 13.94, SD = 0.89) participated in this research in the two different private and public schools. We also adiminstrated for living place both of city and distric, 64.5% and 35.5%, respectively. Furthermore, there have been 8 ethnic has fill-in by students to see students background (i.e., Lampung, Bugis, Batak, Jawa, Manado, Minang, Sundanes, Others).

Instruments

To measure students' MCT, we develop MCT test based on ethnomathematics (MCTtBE). An example of MCTtBE is in figure 1. Data were collected to fill out an online (because of the impact of the Pandemic period). The data collection was conducted between March and June of 2022. Students completed the exam for 120 minutes under the supervision of researchers and teachers. The instruments test will use the ethnomathematics context. In this context, we use Tapis Lampung as a learning resource. These test items cover fluency, flexibility, originality, and elaboration. Fluency refers to producing many ideas, flexibility is having different types of ideas, originality is creating ideas not made by other people, and elaboration is building on a simple answer [35]. Scores are assigned based on classified responses, including fluency, flexibility, originality, and elaboration. Scoring was modifying from Lee & Seo [36]: Fluency, when a student correctly answers multiple questions in a category, the highest possible score is 5; Flexibility, students may write a maximum of 5 responses to a single problem. Thus, the maximum flexibility score is 5; Originality, the score is awarded according to the percentage of frequency: 3% above (score 0), 2% above – 3% below (score 1), 1% - 2% below (score 2), and 1% below (score 3); and Elaboration, the score between 1 and 2. Below is Tapis Lampung pattern. You can see the triangle pattern in this motif. Make five different pictures out of them, based on the triangle pattern you see in the motif. Give a title of each image.

FIGURE 1. An example of MCTtBE (Taken by Author)

Analysis Data

Analytical procedures occurred in online tests were conducted in each school. The data analysis was used SPSS version 25 and Winstep version 5.2.3.0 software [37]. Winstep was utilized for Rasch modeling data analysis. Rasch analysis can accurately and precisely describe an item's difficulty level, detect the suitability and interaction of items and people (item-person maps), identify outliers (person misfit) and detect item bias (differential item functioning (DIF)) are advantageous for describing and identifying students' mathematical creative thinking in this study. Concerning DIF item as having criterias: DIF contrast value of less than -0.5 or more than 0.5, the t-value less than -2.0 or more than 2.0, and *p* (Probability) value of less than 0.05 or more than -0.05.

RESULST AND DISCUSSION

Reliability, Validity, and Item Fit of the MCTtBE

We used a Rasch measurement model for all analyses to see the validity and reliability. The total 20 items was developed and adiminstrated. To see the reliability of items and person are in the Table 1.

TABLE 1. Summary of the Rasch measurement for items and person

PERSON	186 INPUT	186 MEASURED		INFIT		OUTFIT	
	TOTAL	COUNT	MEASURE	REALSE	IMNSQ	ZSTD	OMNSQ	ZSTD
MEAN	34.3	20.0	-.64	.28	1.03	-.2	1.01	-.2
P.SD	8.4	.0	.60	.07	.67	1.7	.70	1.6
REAL RMSE	.29	TRUE SD	.53	SEPARATION	1.81	PERSON RELIABILITY		.77
ITEM	20 INPUT	20 MEASURED		INFIT		OUTFIT	
	TOTAL	COUNT	MEASURE	REALSE	IMNSQ	ZSTD	OMNSQ	ZSTD
MEAN	318.7	186.0	.00	.09	.99	-.4	1.01	-.1
P.SD	189.8	.0	1.02	.02	.34	3.1	.26	2.4
REAL RMSE	.09	TRUE SD	1.01	SEPARATION	11.03	ITEM	RELIABILITY	.99

Table 1 were informed about the item and person reliability. We can see that the reliability for both person and item were excellent to about 0.77 and 0.99, respectively. For Infit MNSQ and Outfit MNSQ has in arrange 0.5 – 1.5. The infit MNSQ for pearson was 1.03 and for item was 0.99. Additionally, the outfit MNSQ for item and person ware same value, to about 1.01. We found the Cronbach's Alpha (KR-20) was 0.76. Furthermore, the raw variance explained by measures was higher than 20%. Contrastly, the students ability was below than average to about -0.64. It is because the pandemic situation may effect on students answering. Its mean that the component were suitible to measure MCT. Speaking for the information function for the test, we also given the graph.

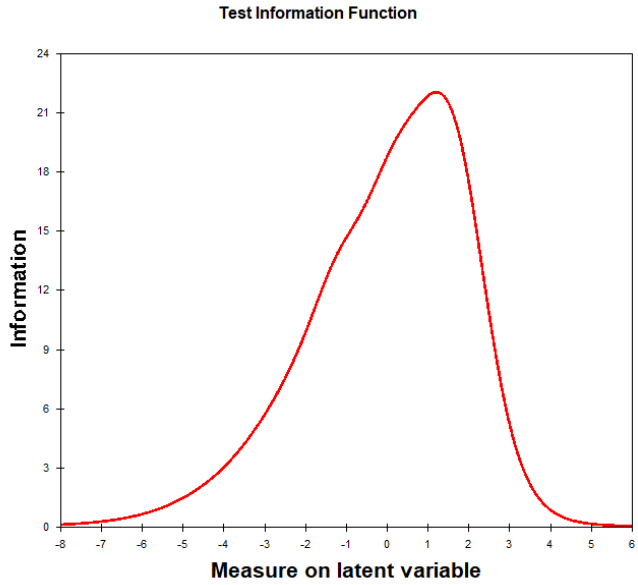


FIGURE 2. The information function of the MCTtBE

Measurement for person ability descibes the students ability in their capability to answering item on task. Regarding on the person ability, wright map ilustrated the propotion between person and item dificulty.

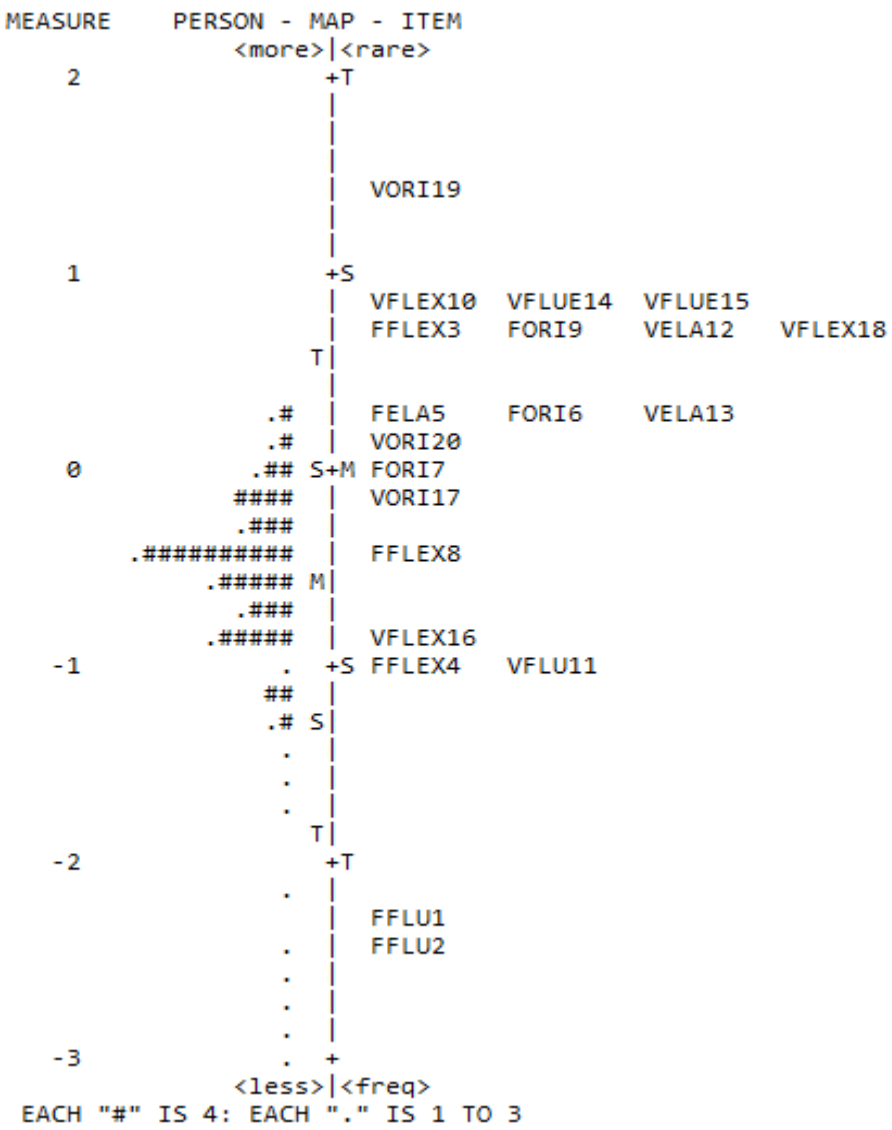


FIGURE 3. Wright map of the MCTtBE (Created by Author)

Figure 3 explaining of the characteristic wright map for person and item in the same scale. It is clear that the test item number FFLU2 was an item easier than VORI19 as difficult item. There are 15 items do not solved perfeclty by students in the average logit (i.e., VORI17, FFLEX8, VORI20, EORI17, FORI16, FELA5, FFLEX3, FORI9, VELA13, VFLEX18, VELA12, VFLEX10, VFLUE15, VORI19, and VFLUE14). Additionaly, 93% students can solved the item.

DIF Owing School Types

Three kinds of criteria can follow DIF. Firstly, DIF t-value is greater than 2.0 or less than -2.0. Secondly, DIF contrast was greater than 0.5 or less than -0.5. Lastly, *p* (probability) value was greater than -0.05 and less than 0.05 [38,39]. The illustration of the DIF can be shown in Figure 4.

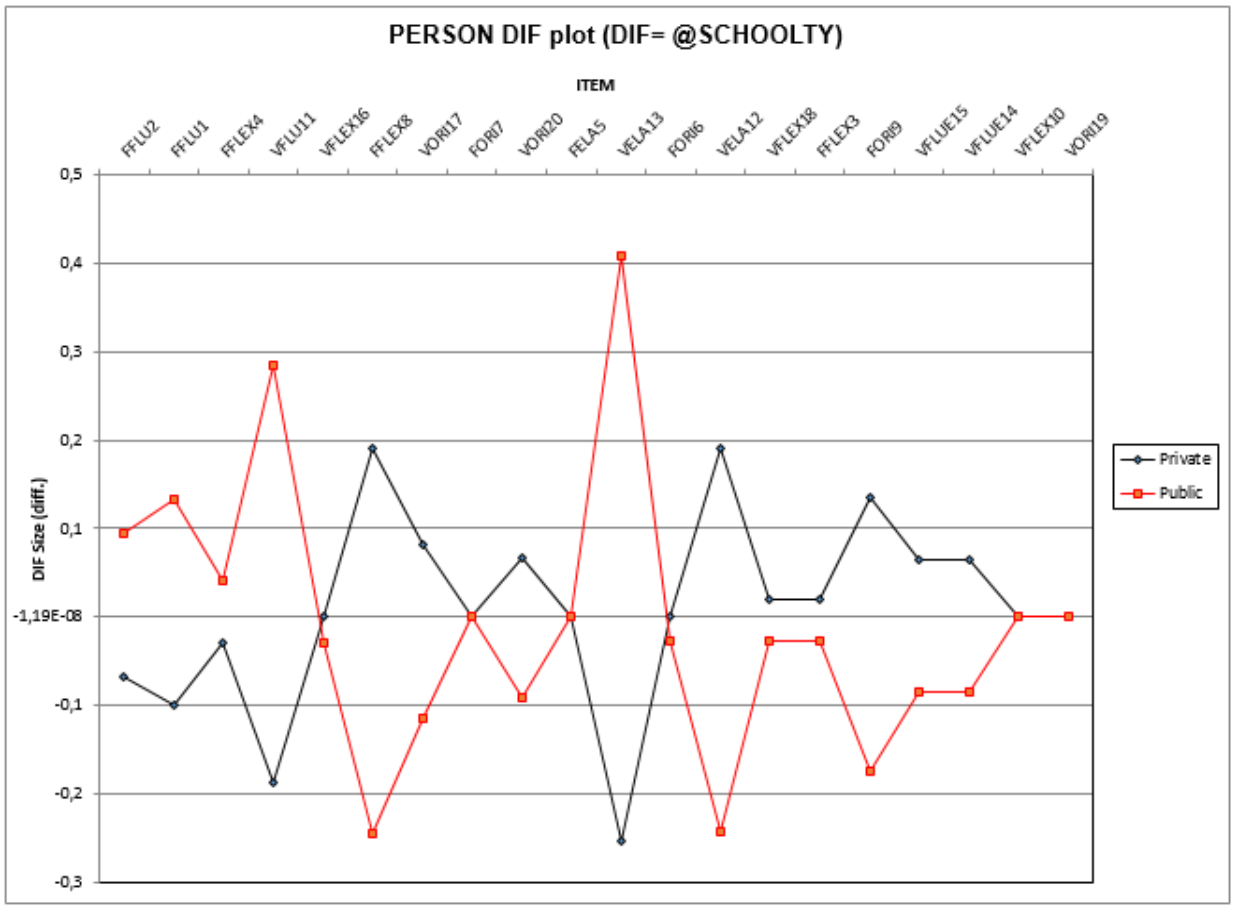


FIGURE 4. DIF based on school types

Figure 4 explains about the DIF view fro school types. Regarding three criteria, the item number 13 is VELA13 as DIF. The value of DIF contrast was -0.66, t-value was -3.67, and *p*-value was 0.0006. It means that the DIF can see the different answering of the students owing school type, both private and public school.

Boys and Girls Performance in MCT

The differences between boys and girls in the MCT performance can be detected by comparing the results test.

TABLE 2. Differences between boy's and girl's performance on the MCTtBE

MCT	Groups	*n*	*M*	*SD*	*F*	*p*	*t*(186)	*p*
Fluency	Boys	71	13.35	2.88	7.36	0.007	0.84	0.404
	Girls	115	12.82	4.89				
Flexibility	Boys	71	10.62	2.16	5.49	0.020	2.48	0.014
	Girls	115	9.57	3.13				
Originality	Boys	71	6.04	2.18	0.06	0.806	-0.05	0.957
	Girls	115	6.06	2.32				
Elaboration	Boys	71	4.83	1.54	1.99	0.160	0.76	0.446
	Girls	115	4.63	1.79				

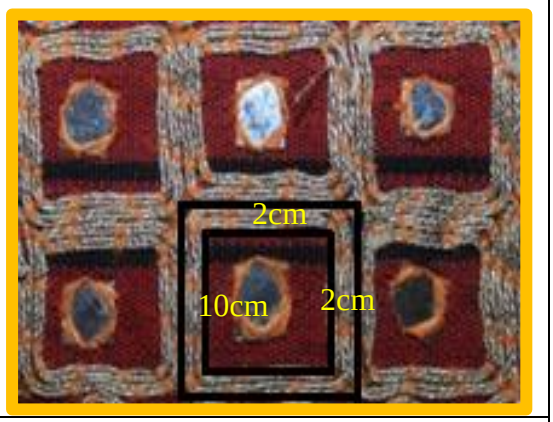
Table 2 indicates the performance of the boys and girls on the MCTtBE in the four categories: fluency, flexibility, originality, and elaboration. We can see that the boys performance in the flexibility test (M = 10.62, *SD* = 2.16) was higher than girls performance (M = 9.57, *SD* = 3.13), $t(186) = 2.48$, $p < 0.05$. Contrastly, there are no differences between boys and girls in three categories: fluency, originality, and elaboration. The example answers of the students' can be shown in table 3.

TABLE 3. An example of students' answers on flexibility questions

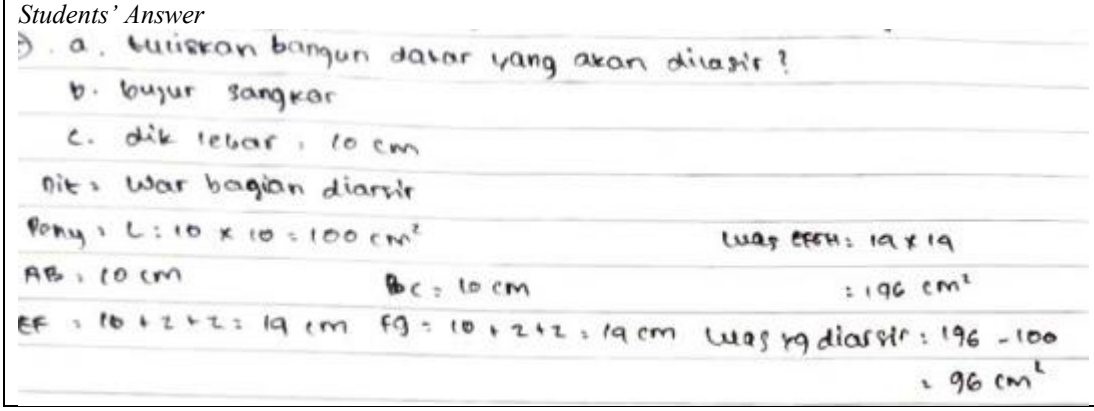
Questions

A square-shaped *Tapis Kaca* with dimensions 10 cm x 10 cm has a 2 cm wide cemented path along its length and a 2 cm wide path along its width (as shown in the figure below).

a. Write down the problem into a question!
b. Write down the data you need!
c. Find the area of the shaded gold portion!
d. Show other ways to determine the area of the shaded gold area!



Students' Answer



Speaking for the person ability that the results was negative. Its can be seen that may effect in the pandemic situation. The mean person measure is -0.64 logits, which shows that, on average, these students aren't very good at MCT. The Person-Item distribution map, also called the Wright map and shown in Figure 3, showed that the students' ability measurements put them right at the mean item of 0.00 logit. Mean items are set to 0.00 logit, and Rasch's theory says that a person has a 50:50 chance of succeeding at a given task. This is the measurement ruler's virtual zero (0). As the item gets harder, the chances of success get lower, giving you less chance to succeed. So, this test has harder questions and the student has a low chance of passing [40].

It is suggested that these students be put in a special program to help them learn more about the MCT. After the first one, they could go on with their program. Some students need extra help to reach the goal of the math subject [41]. This is to make sure that they can keep going with their math studies and won't have any trouble using the ideas in their math field in the future. This test showed how well the students did and what their ability logit measures are indeed. This lets them be put into groups based on how well they did. By using Rasch measurement, the study can again tell which test questions are hard and which are easy for the students. In other words, this can be used to make a good plan for teaching so that the subject is taught correctly and students do their best.

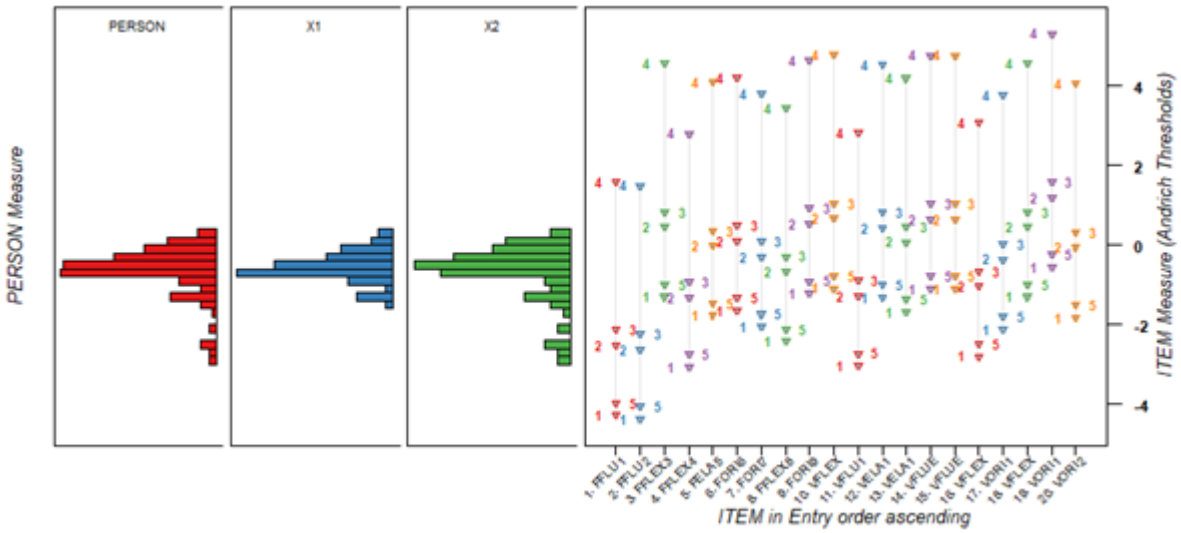


FIGURE 5. Wright map R

Person ability of students can be seen on the figure 5. Blue and green can be joined together as an red colour. Its mean that can be a distribution pattern. The distribution items can also be seen on the right side, from number 1 to number 20.

There are six items do not solve by students'. The items were VORI19, VFLEX10, VFLUE14, VFLUE15, FFLEX3, FORI19, VELA12, VFLEX18. Additionaly, the items to be difficult to the students' with average performance. Contrastly, there are 5 items can be solved by all students, namely FFLU1, FFLU2, VFLEX16, FFLEX4, and VFLUE11. Furthermore, students' performance can be detected by 4 MT categories, namely fluency, flexibility, originality, and elaboration. The performance comparing both female and male. There were differences between boys and girls on the flexibility performance. Unfortunately, there is no differences in three categories fluency, originality, and elaboration.

This study provides new factual evidence and practical suggestions for implementing MCT practices in mathematics classes, even though the expected results did not occur. It also contributes to the literature evaluation of the efficacy of MCT in mathematics education, particularly at the secondary level. This study demonstrates that MCT-based ethnomathematics could be introduced to other school topics, despite some obstacles, such as inadequate teacher training and institutions' reluctance to fully invest in integration [42]. The MCTtBE's instructions and exams were created so that school instructors, curriculum writers, researchers, administrators, and policymakers could utilize them as resources. These tools provide teachers with a clearer and more explicit set of measures to follow while developing and implementing MCT lessons based on ethnomathematics.

The Rasch analysis undertaken in this study allows researchers and teachers to determine if the exams are effective for this group of participants, if they can distinguish people depending on their ability level, and if they are able to identify outlier responses for person-fit analysis. Using the Wright map teaches researchers how to enhance their work and resolve issues in future studies, such as gaps between the items and duplicates. For future study, it is recommended to add more items to fill in the gaps between the current items, revise the items with the same level of difficulty, and create new activities that can comprehensively evaluate the students' talents.

This research has resulted in the development of a valid and dependable method for measuring MCTtBE. This article addresses the shortage of validated tools in mathematics instruction, particularly in the lower secondary level. The submission of sufficient validity and reliability evidence guarantees the quality of the research results. This makes it easy for teachers and researchers to use these exams in the classroom and broadens the dissemination of instruments that employ valid and reliable instruments [43] This study then summarises high school pupils' creative thinking abilities. According to statistical data, the sole difference between men and women is their adaptability.

This study had some limitations. Due to the pandemic situation in the school, it was hard to get more time for correcting answers. So, future studies need to last longer to help students learn math and collect more evidence.

Also, only a small number of students participated in this study, so the results cannot be generalized to the whole population. So, it is suggested that the number of people participating in future studies increase. More research should be done looking at factors like grade level, age, ethnicity, etc.

CONCLUSION

To sum up, the analysis results show that the student performance can be detected by Rash measurement. There is any difference between male and female on the flexibility test. Unfortunately, the groub students were below average with logit value of -0.64. Even the questions was valid and reliable.

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