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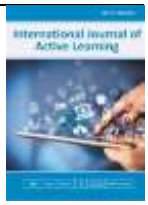

Cognitive Ability Profiles of Junior High School Students with High Mathematical Abilities in Numbers Material Based on TIMSS Domain

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Abstract

The study aimed to describe the cognitive ability of junior high school students in answering questions on whole and fraction numbers based on TIMSS domain. This is a descriptive qualitative research involving three junior high school students with high mathematical ability as the subjects, i.e.: KV, DA, and TE. The data colletion instruments were TIMSS questions on whole numbers and fraction and the interview guidelines. The data were analyzed by using TIMSS cognitive domain in the sections of knowing, applying and reasoning. The results indicated that the knowing stated in written by KV and in mind by DA. Meanwhile TE's ability was limited to compute fractions and measure. While KV applied mathematical concepts in written, DA and TE applied them verbally. TE was less accurate in using the concept of whole numbers. In the context of reasoning, KV was able to propose various solutions, DA had a single solution to fraction qeustions, and TE was confined to fraction questions. The subjects made their conclusions only in written.

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INTRODUCTION

Education is a conscious effort in establishing certain conditions and process of learning to enable learners actively develop their self-potentials in order to possess religious-spiritual power, self-control, personality, intelligence, manners, and skills necessary for themselves (UU RI No 20 Tahun 2003). The effort should be useful in supporting the advance of a nation's education and should be supported by good cognitive abilities. According to Piaget, there are some concepts of cognitive abilities, i.e.: assimilation, accommodation, and scheme (Triwiyanto, 2014, hal. 56). Assimilation is a cognitive process of integrating new concepts and perceptions into a pattern or scheme in mind. Accommodation is a cognitive process of constructing a new scheme or changing an existing scheme based on a new concept. Scheme is a structure which intellectually adapts and changes as one' cognition develops. According to Carroll (1993, p. 10), a cognitive ability is an activity of processing information by mental (brain) thinking. A cognitive ability is also a thinking process emerging from solving problems, which includes understanding and processing information through both new and existing concepts. Problem solving processes may also happen in the context of mathematics problem solving in which the solution will not be the best one if the thinking process does not support the aspects of understanding and processing information.

One indicator of the education quality of a nation can be seen from international survey results. One of them is Trends in International Mathematics and Science Study (TIMSS). TIMSS is an international assessment series of mathematics and science knowledge focusing on the domains of content and learners' cognition. The mathematics content of TIMSS used as an assessment indicator covers topics on numbers (30%), algebra (30%), geometry (20%), data and chance (20%) (2015a, p. 19). The cognitive domain of TIMSS consists of knowing (35%), applying (40%), and reasoning (25%) (2015a, p. 25). In TIMSS, there are four categories of abilities, namely advanced, high, intermediate, and low (2015b, p. 65). Students in the advanced category, having a mean score of higher than 625, are able to apply, propose various solutions, and conclude accordingly. Those in the high category, with a mean score between 550 and 625, have the ability to apply and understand solutions. Students in the intermediate category, having a mean score between 475 and 550, are able to apply mathematical concepts in simple situations. The last category students, those in the low one, have a mean score lower than 475 and know some basics in mathematics.

TIMSS survey is conducted every four year. Indonesia has been in the low category from 1995 until 2015. In 2011, Indonesia scored 386 which earned the 38th rank out of 42 countries (TIMSS, 2011, p. 42). In 2015, Indonesia scored 397 which gave the 44th rank out of 49 countries. This is still in the low category (TIMSS, 2015b, p. 19). This TIMSS low rank of Indonesia has triggered several researchers to investigate the Indonesian students'cognitive ability. A study by Riswan (2013) found out that the Indonesian students in the very low category consisted of four sub categories: very low (39.16%), low (32.42%), medium (21.46%), and high (6.97%). A research by Witri, Putra dan Gustina (2014) also explained that students often had difficulties in answering TIMSS mathematics questions, particularly in the cognitive deduction area. This was confirmed by the fact that the students did only 50% of the whole questions. The difficulties were caused by the students' unfamiliarity with mathematics questions like those in TIMSS and their lack of concept understanding, which eventually did not help them solve complex problems.

This research aimed to describe the cognitive ability of junior high school students having high mathematical ability in answerving TIMSS mathematics questions on numbers. The scope of the research is limited to describing the cognitive ability of junior high school students in the context of concept knowledge, concept application, and concept deduction in answering questions related to fractions and whole numbers. Numbers were selected as this is the first topic to learn according to 2013 curriculum. This topic is taught to seven graders and composes 30% of the total mathematics content of TIMSS.

METHODS

This is a descriptive qualitative research whose data on the students' cognition are in the forms of words, behavior, and images on answering questions on numbers. The explanation of the students' cognitive ability in answering questions on fractions and whole numbers is described in numbers, sentences, and images.

The research subjects were three seven graders of SMP Negeri 2 Salatiga, namely DA, KV, and TE. Based on the final test score in the first semester of 2017/2018, the three subjects are said to have high mathematical ability.

The data collection instruments were six questions of *Tes Kemampuan* [mathematical ability test] (TK), the interview guidelines, and some documents. The questions were adapted from TIMSS mathematics questions on fractions and whole numbers. The description of each question is presented in Table 1. The research data collected were the students' test answer and the interview result.

Table 1. test blueprint

Cognitive domain	Questions
Knowing	Question no. 1 * whole numbers Find the sum of exponentiation whose final result is a rounded-up sum.
	Question no. 2* fractions Find 2 numbers having 2 prerequisites
Applying	Question no. 3 * whole numbers Solve a word problem to find the total packs of paper needed to make school's magazines for a year
	Question no. 4* fractions word problems Find the comparison of two one-year-cellular expenses of two companies, excluding the texts and calls made Find the comparison of two one-year-cellular expenses of two companies, including the texts and calls made
Reasoning	Question no. 4* whole numbers Solve a word problem to find the numbers of cars parked, whose result is a rounded-up multiplication
	Question no. 6* fractions Present a polygonal shape into a circular shape having equal fraction values

*Source: TK1: TIMSS 2003, p. 117, TK2: TIMSS 2003, p. 25, TK3: TIMSS 2003, p. 81, TK4: TIMSS 2015, p. 109, TK5: TIMSS 2007, p. 110, adapted

The data on the subjects' cognitive ability were analyzed by using TIMSS cognitive domain. There are three aspects in this domain. First, knowing as the knowledge of concept and the fluency in the mathematical ability which includes recall, recognize, classify/order, compute, retrieve, and measure. Second, applying as the application of mathematics concept in line with the facts, concepts, and procedure of prolem solving which includes determine, represent/model, and implement. Third, reasoning as the logics in solving poblems which include logical and systematic thinking in order to transfer knowledge as well as skills including analyze, integrate/synthesize, evaluate, draw conclusions, generalize, and justify. The result of the data analysis is presented in the forms of the subjects' cognitive ability profile in answering TIMSS questions on numbers.

RESULTS AND DISCUSSIONS

Knowing

The three subjects' concept knowledge of whole numbers demonstrated the subjects

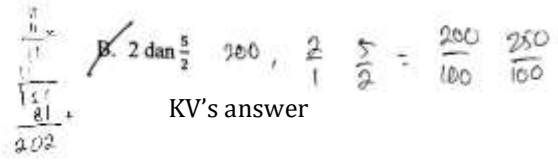
understood the principles of exponents and addition operation of whole numbers. The subjects were able to recall, recognize, and classify/order the exponentiation concept and the addition operation of whole numbers. The subjects were able to obtain the necessary information from the questions that enabled them to proceed to finding the answers.

The subjects differently demonstrated their knowing related to measuring. KV wrote and compute to find the answers while DA and TE directly wrote the answers. The result of the interview revealed that KV did the writing and calculation as she was not yet sure about her answer. Fiture 1.a. shows KV's measuring result. DA and TE used their fingers to calculate without writing down the stages used to find the answers. Although the three subjects used different ways of measuring, they produced the same answer.

KV's and DA's knowing on fractions demostrate their mastery on number sequence principles. Faced with the differences in writing fractions, the decimal or fraction forms, they often uniformly converted into fraction forms. Then, for fractions having the same denominator, KV and DA sequenced them based on the numerator value. The differences lie in the fact that KV wrote the stages of making the denomitors uniform while DA did not; although DA was able to verbally explain the stages of sequencing the fractions.

TE recognized decimals and fractions but were unable to figure out their relation. Unlike KV and DA, TE did not have the compute that enabled her to relate decimals to fractions.

KV, DA, TE answered the questions on fractions differently. KV wrote each step in finding the answers. Figure 1.b shows her work. DA, on the contrary, processed the questions in mind. Both KV and DA could give the correct answers, but TE did not possess the measure aspect to systematically find the answers.



KV's answer

Figure 1. KV's measure aspect on whole numbers

Applying

The subjects' applying related to whole numbers showed that the subject had different strategies to find the answers. Three of them used different ways of determine and represent/modeling the information obtained from the question. While KV wrote down the important points, DA and TE explained it orally. During the interview, KV explained that she wrote down the points as to ease her do the calculation. DA and TE, having understood the questions, did not feel the need to write down the important points. Figure 2 shows KV 's represent/model.

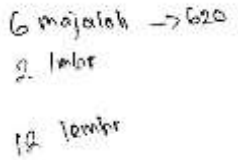


Figure 2. KV's represent/model of whole numbers

The subjects' solving strategies are considered as a strategy implement process. The three figures below show different strategy implement processes. Figure 3.a shows how DA used multiplication rows to find 620 x 12 then stopped writing after finding the answer. She figured out the rest of the calculation in her mind. Figure 3.b shows how KV found 620×12, continued to divide the previous answer by 500, and wrote her conclusion with the final figure. Figure 3.c shows how TE found 620×12 and continued to divide the previous answer by 500. DA and KV had the same answer and were said to have appropriately applied their strategy. TE miscalculated 620×12, and, thus, had a different answer.

DA's answer KV's answer TE's answer

Figure 3. The subjects' implement aspect on whole numbers

The subjects' applying of fractions show that the subjects were able to verbally explain the complete information from the question. They also

had and used different strategies to find the answer, which was the same. Figure 4.a shows how DA used rows in the calculation without writing the companies' name. Figure 4.b shows how KV used rows in the calculation, separated the ownership from each company, but did not write the price unit used. Figure 5 shows how TE wrote down the calculation in one line, separated the ownership from each company, and wrote the price unit used.

DA's answer KV's answer

Figure 4. DA's and KV's implement aspect on fractions

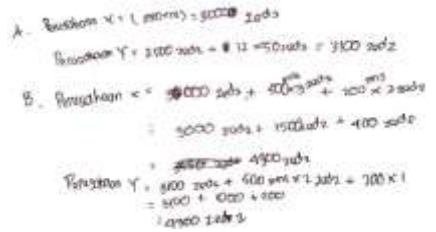
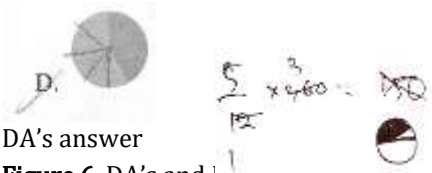


Figure 5. TE's implement aspect on fractions

Reasoning

The subjects' reasoning on whole numbers showed that the three subjects were able to analyze and integrate/synthesize information according to the principles of multiplication and round up/rounding down. The subjects also had several different ways to find the answer. DA and KV had two ways of finding the answer. Their first way is multiplying the numbers and rounding up the answer. The multiplication was done to find 68 x 92. The result was, then, rounded up. The second is doing the rounding to the nearest known numbers and multiplying the numbers. The rounding up was done to number 68 dan rounding up to 92. The result was then multiplied. TE only thought of only one solution, i.e.: the rounding to the nearest numbers and multiplying the numbers. All subjects were able to withdraw a generalize conclusion and justify the argument of each step mathematically. Although the three of them had the same answer, they did draw conclusion which they were able to explain verbally.

The subjects's reasoning on fractions also show that the subjects have different abilities to analyze questions on fractions. DA and KV were able to analyze and integrate/synthesize the fractions made of groups of planes and convert the planes into circles. TE ignored the fact that the fractions were made of groups of planes but tried to convert the planes into circles. DA and TE had the evaluation aspect of fractions, but KV did not. DA had one solution, i.e.: divide the circle into several parts representing the fractions made of the plane group. TE was unable to apply the mathematical concept of fraction conversion to find the answer. KV had two solutions. The first was estimating. The second one, the evaluation step, was multiplying the fractions represented by the figures to 360^0 in one circle as shown in Figure 6.b. Although experiencing difficulties in applying mathematical concepts when working on the question, the three subjects produced the same answer but did not draw the conclusion. During the interview, the subjects were able to make generalize conclusions of each step they used to apply them to similar questions. They were also able to mathematically reviewed each step they used.



DA's answer

Figure 6. DA's and KV's evaluate aspect on fractions

Discussions

The research findings pointed that although the subjects had high mathematical ability, they did not have the same cognitive ability. In the knowing, KV's conceptual ability was similar to DA's but not to TE's. KV was able to give the correct answers and write her conceptual ability. DA was able to give the correct answers but did not express her conceptual ability in written. TE's ability was limited to the compute aspect on fractions and to the measure aspect of whole numbers and fractions. These findings support the studies done by Kablan dan Kaya (2013) which

stated that it took a good conceptual knowledge in order to be able to answer TIMSS questions. Mawaddah and Maryanti (2016) also stated that the concept knowledge of junior high school students were good.

In the applying, the three subjects did almost a similar process to fulfil each aspect. KV was able to write her understanding of the questions on fractions and use the mathematical concept to find the correct answers. DA was able to verbally express her understanding of the questions and use the mathematical concept to find the correct answers.

DA was able to verbally express her understanding of the questions but was not accurate in using the mathematical concept to find the answers. These findings confirm some previous studies (Amelia, Susanto, & Fatahillah, 2015; Sulistyorini, Pujayanto, & Elvin Yusliana Ekawati, 2013) which stated that the junior high school students' ability to apply concept was good, with the percentage of 71.2%. However, their being less accurate caused difficulties in understanding questions. This, therefore, contradicts the study by Fatqurhohman (2016) which pointed the students' lack of concept mastery as the cause of the problem.

In the reasoning, there were differences as well as similarities. The differences lie in the numbers of solutions proposed. KV's concept knowledge ability enabled her to think of various solutions. DA's ability enabled her to propose a single solution to fraction problems. TE, however, had a limited concept knowledge ability on fractions. The similarity is shown by all subjects' limited ability to express their conclusions in written. These findings support several previous studies (Agasi & Rudhito, 2014; Anisah, Zulkardi, & Darmawijoyo, 2011; Ario, 2016; Putrawangsa & Hasanah, 2018) which stated that the deduction or reasoning ability of junior high school students were said to be fair although some students had poor ability. Those subjects had difficulties in understanding the questions and concepts as well as writing out their reasons since they mostly stuck to the calculating procedure. This contradicts the previous study by Susanti (2016) which concluded that the sudents' reasoning ability to answer TIMSS questions was good.

CONCLUSION

This study found that the three subjects had different profiles of ability to answer questions on whole numbers and fractions. KV's knowing profile was "able to express her conceptual knowledge in written and find the correct answers. DA's knowing profile was "able to do the abstract thinking and find the correct answers. TE's knowing profile was "limited to the compute aspect of fractions and the measure aspect of whole numbers and fractions".

KV's applying profile was "able to express her understanding of the questions in written and accurately use the mathematical concept to find the correct answers". DA's applying profile was "able to express her understanding of the questions verbally and accurately use the mathematical concept to find the correct answers". TE's applying profile was "able to express her understanding of the questions verbally and use the mathematical concept less accurately to find the correct answers to the questions on whole numbers".

KV's reasoning profile was "able to propose various solutions but was not good in writing down the conclusions". DA's reasoning profile was "able to propose a single solution to the questions on fractions but was not good in writing down the conclusions related to whole numbers and fractions". TE's reasoning profile was "show limited concept knowledge ability to answer the questions on fractions and limited ability to write down the conclusions related to whole numbers and fractions ".

The study recommends teachers to emphasize their teaching on the mathematical concept knowledge and application and to add more questions requiring the mathematical concept deduction. The emphasis and the questions should reflect the application of the mathematics problem into daily life, as shown by TIMSS questions. In addition, further studies are expected to involve subjects with medium and low mathematical abilities.

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