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Abstract

The intention of the present study is to know how students' performance on number sense based on the components of number sense and also the sub-components in it. The participants of the study are 80 six graders (12-13 year-old) from three different schools that represent the city, rural, and small town areas. The data were collected using the test. The data analysis showed that the elementary school students' performance on number sense was still weak on the component of understanding the meaning and concept of numbers. This could be seen in 23.53% respondent. The highest average was 49.75% in understanding the meaning and effect of operation. Nevertheless, the students' responses indicated that most of those were more dominated by the written algorithms in solving problems. This was also happened on the component of applying knowledge and number sense and operation in computational situation. The students found some difficulties in understanding the meaning and concept of numbers, especially on the domain of fraction and decimal. There were some obstacles the students had, such as misconception about the density of fraction and decimals, about the concept of the part of fraction, and some errors when doing the computation because they paid more attention to the rules and algorithms they understood.

Keywords: number sense, numbers, written algorithm, elementary school students, Indonesia

1. Introduction

1.1 Background

Numbers is one of the most fundamental mathematics concepts in the elementary school that aims in (1) solving daily-life problems, (2) being the base of all mathematics curriculum, and (3) developing the sense about the numbers itself (National Research Council [NRC], 2001; Anghileri, 2006). Moreover, NRC (2001) stated that the concept of numbers is useful as the base of all mathematics curriculum and also useful in understanding the concept of measuring, geometry, algebra, and data analysis. By learning the concept of numbers, the students are expected to be able to appreciate the beauty and the importance of mathematics.

Some studies that have been done in Indonesia showed that students' understanding of numbers is still weak especially in doing the computation or counting. This was happened because students' ability in computation was more dominated by the written algorithm (Herman, 2001; Purnomo, 2013). With written algorithm, students had to find the solution of 38 + 25, 43 – 14, 28 × 8, or 64 ÷ 16. Many times, students did some errors in doing the algorithm when they tried to solve the above problems. In Sumarto, van Galen, Zulkardi, & Darmawijoyo (2014), Zulkardi stated that there are the collection of rules and algorithms in most of the school textbooks in Indonesia. This indicated that students were many times faced with the mechanistic instructions of stiff procedures of algorithm.

Students' understanding about numbers is not only about being able to do the counting procedure based on the written algorithm, but also about students' sense of numbers itself. According to McIntosh, B. Reys, and R. Reys (1992), the numbers sense refers to someone's common understanding of numbers and the operation between them and also someone's ability and tendency to use the understanding in making flexible mathematics decision and to develop useful strategies to master it. Moreover, Gersten and Chard (1999) described number sense with a new construction that refers to students' fluidity and flexibility with numbers, their sense about the meaning of numbers and their ability in doing mental mathematics and seeing the world and making comparison. In other words, number sense is one's ability in understanding the concept and procedures of numbers and its operation, and in using it to make mathematics decision with various effective, efficient, and flexible strategies.

The number sense teaching and learning is very important to be done in the elementary school because of some reasons. Yang and Wu (2010) had synthesized that there were at least four reasons behind the importance of number sense. First, number sense is a way of thinking that represents flexibility, inventiveness, efficiency, and reasonableness. For instance, when students were asked to find the solution for 24 × 65 ÷ (6 × 13), they usually used the written algorithm such as 24 × 65 = 1560, 6 × 13 = 78, and 1560 ÷ 78 = 20. For many students, these strategies were somewhat hard to be followed. More efficient and effective strategies that could be used by the students were knowing that 24 ÷ 6 = 4, 65 ÷ 13 = 5, and then 4 × 5 = 20. Second, number sense is a holistic concept of quantity, numbers, operation, and the relationship among them, that can be applied efficiently and flexibly in daily-life situation. Third, some adults is depending on number sense to think mathematically and to represent numbers. Forth, the over-emphasized on the written counting procedure is not only impeding students' mathematics thinking and understanding, but also obstructing their number sense ability. Beside those reasons mentioned above, the number sense is also facilitating someone to solve problems, to give reason to something, and to discuss mathematical idea (Shumway, 2011).

The understanding of number sense is important because it has a unique and meaningful contribution to the mathematics learning. The power of number sense's prediction was also getting stronger from time to time (Jordan, Glutting, & Ramineni, 2010). Moreover, in seeing the early picture of developing number sense ability is useful to identify the students with difficulty in mathematics later on (Jordan, Kaplan, Locuniak, & Ramineni, 2007). The teachers have to be able to see the importance of understanding the number sense for their elementary school students.

Assessing number sense is an important and challenging strategy to the curriculum designers and mathematics researchers (Yang, Li, & Lin, 2008). It is also important to the teacher as a tool that can be used in the classroom to see students' understanding of concepts and procedures of numbers and the operation. Number sense has been an international study topic in order to develop mathematics education, even until now. Ironically, number sense has not been understood clearly by the school-teachers yet (Faulkner, 2009).

McIntosh et al. (1992) suggest that there are at least three components of number sense that can be assessed from students' number sense ability, such as (1) knowledge of and facility with number, (2) knowledge of and facility with operations, and (3) applying knowledge of and facility with numbers and operations to computational settings. These three components have been used as a basis of some international studies to access number sense qualitatively, quantitatively, and even the combination between those two (see Reys et al., 1999; Tsao, 2004; Singh, 2009; Yang, R. Reys, & B. Reys, 2009; Yang & Wu, 2010; Tsao & Lin, 2011; Courtney-Clarke, 2012). The three components of number sense aforementioned will be described clearly on Table 1 on the next page.

1.2 Objectives of the Study

Since the understanding of number sense is important for the next step of mathematics learning, by assessing students' performance on number sense, the teachers can reflect their instruction as the first step to develop number sense, especially for elementary students. The intention of the present study is to know how students' performance on number sense based on the components of number sense and also the sub-components in it.

2. Method

2.1 The Participants

The participants of the study are 80 six graders (12-13 year-old) from three different schools that that have been randomly chosen to represent the city, rural, and small town areas. These grades were chosen because the researchers wanted to see students' number sense performance after their learning process in their first to sixth year of elementary school. There were 46 students from the city school, 21 students from the rural school, and 13 students from the small town school.

2.2 Data Collection

2.2.1 Instruments

There was a test conducted to collect the data that would be used in identifying students' performance of number sense. In order to validate the test instruments, beside consulting them to the experts, the researcher also adapted the items of the test to every components of number sense from McIntosh et al. (1992) and adopted some items from the study of McIntosh, B. Reys, R. Reys, Bana, and Farrell as cited in Singh (2009). The researcher kept the original contents of some adopted questions, but those questions were then re-designed by translating them into Indonesian language, the difficulty level of the questions was adapted into the elementary school curriculum in Indonesia, and the numbers of questions were reduced into 30 items. The reliability of the test was tested using Alpha Cronbach at the coefficient of 0.73 (more than 0.7) so that it could be concluded that the test was reliable (Budiyono, 2003).

Table 1. The number sense components with each indicator

The number sense components	Indicators/ Sub-components	Test items
Knowledge of and facility with numbers	Sense of the order of place value on the number line	2, 10, 11, 30
	Sense of various representation of numbers	7, 14, 16
	Sense of the absolute and relative value of numbers	3, 9, 29
	System of benchmarks	6, 27
Knowledge of and facility with operations	Understanding the effect of operation	21, 22, 23
	Understanding the nature of operation in numbers	18, 24, 25
	Understanding relation between operation	4, 5, 13, 20
Knowledge of and facility with numbers and operations to computational settings	Understanding the relation between the contexts of the problems and the appropriate computation	12, 26, 28
	Awareness of various strategies	15, 19
	Tendency to use a representation efficiently	1, 8
	Tendency to review the data and the reasonable results	17

2.2.2 Procedure

The test of number sense was given to all of the participants that voluntarily agreed to participate in the present study. Before conducting the test, the rules in doing the test were read by the researcher, which were: (1) the participants were not allowed to start doing the test until the command was given by the researcher; (2) they were given 1 minute and 10 seconds to solve every questions; and (3) they were not allowed to move on to the next question and/or move back to the previous one until the time was over. The time was controlled by the researcher when the participants were doing the test so that they could use their intuition rather than the written algorithm, and they could predict the reasonable result.

2.3 The Data Analysis

The scoring procedure to every test items except for items number 2, 10, 11, 27, and 30 was given 1 to every correct answer and 0 to the incorrect answer. The score 2 was given for the items number 2 and 30 for the correct answer and reason, 1 for correct answer but incorrect reason, and 0 for incorrect answer with no attention to the reason whether it was correct or incorrect. For the items number 10, 11, and 27, the score given was 2 for all answers were correct, 1 for only one answer was correct and the other was incorrect, and 0 for all answers were incorrect. The total of the scores that was possible were 35. The data was then analyzed quantitatively to see the mean, median, and the standard deviation for every component of number sense. The percentage of the respondent's correct answers was used to see their performance in every item in the test of number sense.

3. Results

The analysis of number sense performance was categorized base on every component of number sense by paying attention to the mean, median, and the standard deviation. The analysis was then continued by seeing the number of respondents giving the correct answer (in percent) on every item in each sub-component of number sense. The description of students' performance base on the component of number sense and the performance analysis for every item on each of the component of number sense was given below.

Table 2. Performance in every component of number sense

N = 80	Knowledge of and facility with numbers	Knowledge of and facility with operations	Knowledge of and facility with numbers and operations to computational settings
The number of questions	12	10	8
Mean	26,35%	49,75%	42,19%
Median	18,5	38,5	29
Standard deviation	19,48	16,55	25,5

On the Table 2 above, it can be seen that the students' performance was low on the component of knowledge of and facility with numbers. We can conclude it by seeing the average the students get was 26.35% out of all the respondents. The highest average, 49.75%, was in the component of knowledge of and facility with operations. Overall, the result showed that students' performance in computation was better than their understanding about the concept of numbers.

3.1. Knowledge of and Facility with Numbers

On this first component of number sense, there were 26.35% respondents gave the correct answer, which was also the lowest average among the other two components. There were 12 questions about the component of understanding the knowledge of and facility with numbers, consists of the sub-component sense of the order of numbers, sense of various representation of numbers, sense of the absolute and relative value of numbers, and using the standard criterion of measuring. Below were the data of respondents' correct answer on every item for the first component.

Table 3. Percentages of the correct answer the respondents given on every item for the first component

Sub-component	The item number	The number of respondents giving the correct answer	Percentage
Sense of the order of numbers	2	0	0%
	10	3	3,75%
	11	8	10%
	30	0	0%
Sense of various representation of numbers	7	37	46,25%
	14	1	1,25%
	16	28	35%
Sense of the absolute and relative value of numbers	3	44	55%
	9	49	61,25%
	29	10	12,5%
System of benchmarks	6	27	33,75%
	27	46	57,5%

There were two items of this component that more than 50% respondents gave their correct answers, those were the item number 9 and 27. Each of those represented the sub-component of the sense of the absolute and relative value of numbers, and the system of benchmark.

The lowest results found in the sub-component of sense of the order of numbers, in which there were not more than 10% respondents gave their correct answers. This sub-component consisted of four questions related to the density of fraction, decimals, locating the number on the number line, and putting the number on the number line. The items number 2 and 30, respectively represented the nature of the density of fraction and decimals, were hard enough to be solved by most of the participants. The following are students' work with the misconception on the nature of the density of decimal (see Figure 1) and fraction (see Figure 2).

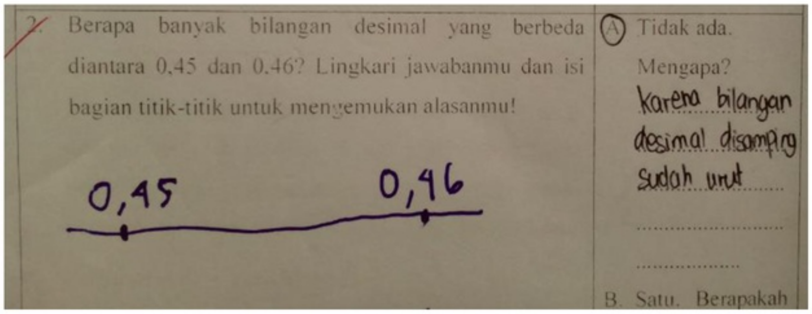

Figure 1. Avira's answer

Translation:

2. How many different decimals numbers between 0.45 and 0.46? Circle your answer and then fill in the blank to write the reason!

A. None. Why? _______________

B. One. What is it? _______________

C. A few. Give Two Examples. _______________ *and* _______________

D. Many. Give Three Examples. _______________ *and* _______________ *and* _______________

Avira's answer: A. None, because those two decimals was already ordered correctly.

Avira used her understanding about the order of the natural numbers and saw that after 45 would always be 46. It was incorrect because the decimal order was different with the order of natural numbers. The numbers between 0.45 and 0.46 could be seen as the numbers between 0.450 and 0.460, or between 0.4500 and 0.4600, etc.

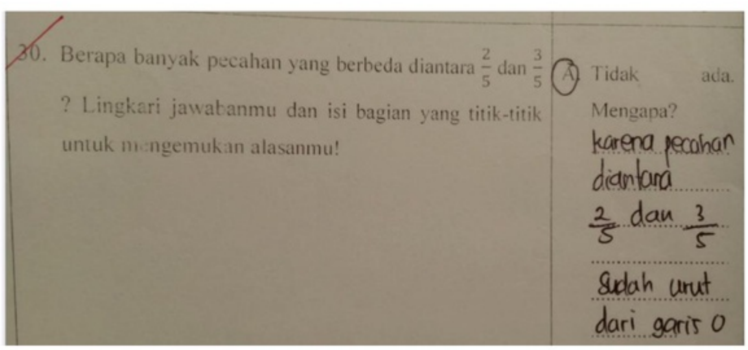

Figure 2. Gretha's answer

30. How many different fractions among 2/5 and 3/5? Circle the best answers and write your reason in the blank area!

Gretha's Answer: No one, because later 2/5 is 3/5.

This was quite the same with what happened on the item number 2, Gretha saw that after 2, there was exactly number 3 so that she concluded that there was no fraction between them. To see the fractions between 2/5 and 3/5, we can see the the proportion between those two, such as 4/10 and 6/10; or 6/15 and 9/15; and so on.

Both two answers students gave aforementioned represented almost 95% misconception the students had. They thought that there was no different numbers between 0.45 and 0.46 (or 2/5 and 3/5 in the case of fractions) because those numbers were already ordered correctly and written adjacently. The misconception that commonly happened in the students' mind was that they used their understanding about the natural numbers in the number line to solve the fraction (decimal) order and density problems. The nature of the density of fraction required the understanding that there were infinite fractions between two fractions with different proportion. The nature of density was also applied on the decimal numbers because decimals could be seen as a representation of fraction on the base-ten notation.

Still about the first component, misconception also occurred when the students were asked to represent the fraction visually on the item number 14 below.

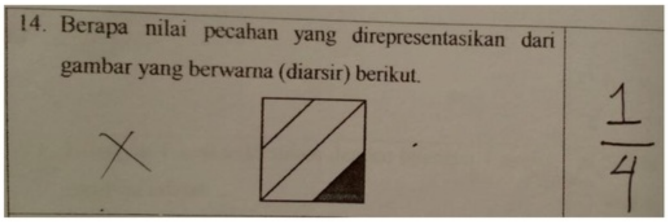

Figure 3. Sofyan's answer

Translate:

14. What's fraction that represented following figures.

Sofyan's answer: 1/4.

Seventy-eight participants wrote 1/4 for the answer of this item, 1 participant answered 1/3, and only 1 participant answered 1/8. Most of the students saw the concept of fraction by counting the shaded part as the numerator and the whole part as the denominator without considering if the size of each part was equal. The correct concept of fraction needs us to find out the fair part of the whole, by considering both the numerator and denominator.

3.2 Understanding the Meaning and Effect of the Operation of Numbers

This component had the highest average compared with the other two components, 49.75%. There were 10 items in this component that represented three sub-components in it. Those sub-components consisted of understanding the effect of operation, natures of numbers operation, and the relation between numbers operation. The percentage of respondents that gave the correct answer on every item was shown below.

Table 4. Percentage of respondents that gave the correct answer on every item of the second component

Sub-component	The item number	Number of respondents answered correctly	Percentage
Understanding the effect of the operation	21	20	25%
	22	34	42,5%
	23	48	60%
Understanding the nature of numbers	18	25	31,25%
	24	23	28,75%
	25	25	31,25%
Understanding the relation between numbers operation	4	57	71,25%
	5	43	53,75%
	13	63	78,75%
	20	60	75%

Based on the Table 4 above, all questions on the sub-component understanding the relation between numbers operation had more than 50% respondents answered correctly. The items number 13 was the question that had most respondents answered correctly. However, most of students' work consisted of their hand-writting on the answer sheet. This indicated that the students still paid more attention to the written algorithm, by counting each operation, and then compared the results of each counting. Figure 4 below is showing the question and an example of students' answer.

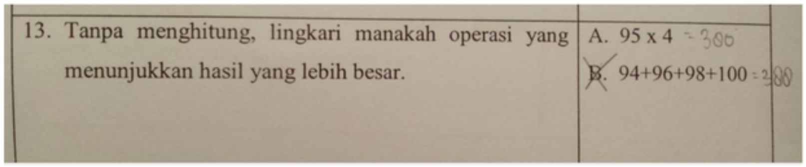
13. Tanpa menghitung, lingkari manakah operasi yang menunjukkan hasil yang lebih besar.
A. 95 x 4
B. 94+96+98+100

Figure 4. Hasanah's answer

Translation:

Without calculation, circle the expression which represents the larger amount.

A. 95 × 4

B. 94 + 94 + 98 + 100

Hasanah's answer: B. 94 + 94 + 98 + 100

The above question could be efficiently and effectively answered by looking at the relation between those two operations. Multiplication can be seen as repeated addition, so that 95 × 4 was another way to express 4 × 95 which meant the addition of four 95s. From the expression of repeated addition, it could be seen than 94 + 96 + 98 + 100 had a bigger result.

The item number 21 had the lowest percentage of students who answered correctly, that was 25%. The item asked students to use their understanding about how to multiply one-digit number with another one-digit number. Most of the students' answers showed that those multiplications would result also a one-digit number. The mistake that could be happened was that the students initially multiplied the numbers with one so that the multiplication of one-digit numbers would result one-digit numbers also. They concluded the solution of their initial idea could be generalized to all problems.

There were not more than 32% of respondent gave the correct answer to the second sub-component. This was the lowest achievement among the other sub-components in the second component. On the other side, the result didn't show that the students used their understanding about the nature of operation. It could be seen that instead of using the more effective and efficient strategy by considering the nature of operation, the students mostly used the strict computation rules. This finding proved that most of the students prefer to use their understanding in using the written algorithm procedure to their intuitive understanding about numbers, operation, and the relation between them.

3.3 *Knowledge Of and Facility with Numbers and Operations to Computational Settings*

There were 42.19% students gave the correct answers to this component with 8 questions represented four sub-components. Below is the amount of respondents answered correctly every items on this third component.

Table 5. Percentage of the amount of respondents answered correctly every item on the third component

Sub-component	The item number	Amount of respondent answered correctly	Percentage
Understanding the relation between the context of the problems and the appropriate computation	12	30	37,5%
	26	18	22,5%
	28	62	77,5%
The awareness of various strategies	15	3	3,75%
	19	11	13,75%
The tendency to use a representation and/or an efficient strategy	1	28	25%
	8	78	97,5%
	28	62	77,5%
The tendency to review the data and reasonable results	17	40	50%

On this third component, the lowest result was in the sub-component of awareness of various strategies. It could be seen that there were less than 14% respondents gave correct answer to each questions in this sub-component. Below was an example of students' answer when they were asked to use various strategies in answering the daily-life problems related to the percentage.

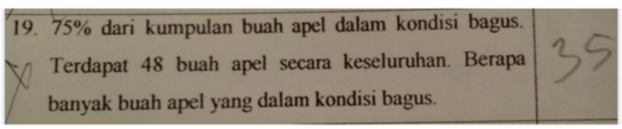

Figure 4. Safira's answer

Translation:

75% of a set of apples has a good condition. There are 48 apples in the set. How many apples that have the good condition?

Safira's answer: 35

There were so many strategies that could be used, one of those was to think that 48 apples could be represented as 100%. We could think that in order to find out 75% of it, we could initially find out 25% of it. Dividing 100 by 4 could do this, so that 25% of 48 apples were 12 apples. By understanding this, 75% of apples were the same with 36 apples.

The highest percentage of respondents who answered correctly was in the indicator of the tendency to use a representation and/or an efficient strategy on the item number 8. The students were asked to do the subitizing by seeing the pattern they already knew.

Overall, students' performance at the third component was higher than the other two. Nevertheless, there were some indications that most of the students dominantly used the written algorithm. This could be seen from the students' written work when using the rules of operation that far simpler to be remembered when they only had a short time to think.

4. Discussion

The result showed that there were 26.53% of respondents gave the correct answer to the component of knowledge of and facility with numbers; 49.75% of respondent gave the correct answer to the component of knowledge of and facility with operations; and 42.19% of respondent gave the correct answer to the component of knowledge of and facility with numbers and operations to computational settings. The lowest performance was in the first component in which there was a need about mastering the conceptual understanding rather than the procedural understanding that could be found in the other components. This finding showed that most of the students were more dominated by the procedural understanding than the conceptual one. Students' understanding was very related to the procedural understanding. If there was no conceptual understanding, it would be hard to observe and evaluate the error in the process of solving problems. This would lead to the error potential in developing the intuitive and conceptual understanding (Byrnes & Wasik, 1991; Widjaya, Stacey, & Steinle, 2008; Forrester & Chinnappan, 2010; Singh, 2009).

The weakness on the first component was in the sub-component of the sense of the order of numbers, which not more than 10% students answered correctly. There was a misconception that the students used their understanding of natural numbers to solve the fractions and decimals problems. Locating the natural numbers in the number line could be illustrated by placing the same-distanced dots on the number line, but this was different with fractions and decimal numbers. There would always be infinite number of fractions between every two fractions with different place value. This was the epistemological learning obstacle has to be anticipated by mathematics educators and researchers that the prior knowledge, which has been considered as the right concept and could be used in solving particular problems, later became inappropriate to be applied in solving new problems.

Moreover, there was also a misconception in understanding the concept of fractions in the sub-component of the sense of numbers representation. Holistically, students saw the part of fractions by counting the whole part without considering the concept of fair division. This was in line with the finding from Suryana, Pranata, and Apriani (2012) in five different schools in Indonesia which all students only saw the number of the shaded part without considering the fair division as mentioned above. The teacher has to be able to see this to create the various representations of fractions, for instance by using two models of both congruent and non-congruent fractions with concrete materials so that the students can understand that the concept of fractions is about the fair division.

The highest performance was found in the second component and the third one. However, the average of the second component was still below 50%. The lowest average was in the sub-component of understanding the nature of numbers. The students used to be more familiar with the written algorithm of operation and paid a little attention on the nature of operation. This would lead to the error in applying the algorithm in solving problems. It could also be seen that there was a close relationship between the procedural and conceptual understanding. The procedural computation could only be applied correctly with better conceptual understanding. This kind of problem was also found in the other second sub-component and most of the third sub-component.

Having showed the students' performance on the range of 26% to 50%, it could be concluded that students' number sense performance was low in the conceptual understanding. In addition, the teacher has to give more attention to the fractions and decimal domain. The result was closely related to the teaching materials the teacher chose. The instruction the teachers designed many times related to the teaching materials used in the classroom. When the teaching materials are dominated with the written rules and algorithm, the teachers tend to design the mechanistic approach in teaching so that the students are not facilitated to be a good problem solver. There are some suggestions in developing students' number sense that can be concluded from this study, such as: giving some activities that can support students' connection skills, exploring and discussing the concept, making sure that the order already suits the concepts, and connecting the problems to students' reality (Yang, 2002; Griffin, 2004; Yang & Wu, 2010). The suggestions given can be included into the instruction in the classroom or be integrated into the teaching materials.

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