The difficulties of Indonesian fourth graders in learning fractions: An early exploration of TIMSS 2015 results

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Abstract. The present study investigates Indonesian fourth-graders low performance in dealing with fractions in TIMSS 2015. Furthermore, the present study also explores possible reasons for this low performance. The data for this study was drawn from TIMSS 2015 data which included test results and responses to Teacher Questionnaire. Descriptive statistics was used to analyze the data. Indonesian textbooks were also analyzed to portrait a broader scope of possible reasons for students' low performance. The analysis of TIMSS test result reveals that Indonesian students, in comparison to students from other countries, had low understanding of the basic concepts of fractions. From the Teacher Questionnaire it was found that a possible reason for this low understanding was the Indonesian curriculum for third grade which gave low emphasis on the basic concepts of fractions and introduced operations of fractions rather early. Furthermore, the result of textbook analysis shows that Indonesian textbooks restricted only to one definition of fractions, i.e. fractions as parts of wholes. This finding might also explain Indonesian fourth graders' low understanding of fractions.

INTRODUCTION

Indonesia has regularly been participating in the Trend in International Mathematics Studies (TIMSS) since 1999. After joining the TIMSS Mathematics – Eighth Grade for four periods, in 2015 Indonesia for the first time joined the TIMSS Mathematics – Fourth Grade assessment. In addition to TIMSS Mathematics – Fourth Grade, Indonesia also participated in TIMSS Numeracy. TIMSS Numeracy is developed for low performing countries where the majority of their children are still lack of fundamental mathematics skills. In general, TIMSS Numeracy is similar to TIMSS Mathematics – Fourth Grade but it uses mathematics test items with lower complexity and covers less difficult topics.

The structure of the mathematics tasks which are used in TIMSS – Fourth Grade are similar to the tasks for the eighth graders. These tasks comprise two domains, i.e. content domain and cognitive domain [1]. Content domain refers to the mathematics contents to be assessed. For fourth graders there are three domains of content, i.e. numbers, geometric shapes and measures, and data display. In addition to these content domains, students also have to deal with cognitive domains that measure the level of their cognitive skills. These cognitive domains include knowing, applying, and reasoning. The domain knowing mainly deals with factual, conceptual, and procedural knowledge of students. The second domain, applying, focuses on measuring students' ability to apply their conceptual understanding to solve various problems. The third domain, reasoning, deals with non-routine problems with complex contexts that mostly require multiple steps.

Similar to the results of Indonesian students in TIMSS – Eighth Grades in previous TIMSS assessments, the performance of the Indonesian fourth graders in TIMSS are also low. The average score of Indonesian fourth graders in TIMSS 2015 is 397, which is far below the TIMSS scale centerpoint of 500. With that score,

Indonesia ranked 44th out of 49 countries. Only five countries were below Indonesia, i.e. Jordan (388), Saudi Arabia (383), Morocco (377), South Africa (376), and Kuwait (353). When zooming in on the TIMSS tasks which address the topic of fractions, it was found that the average percentage of correct answer of Indonesian students, i.e. 24,45%, was below that of the countries with lower TIMSS score which included Saudi Arabia (29,42%) and Kuwait (25,18%). A similar result was found for TIMSS Numeracy in which on average 42,67% Indonesian students could solve fraction problems correctly, whereas 46,76% Jordanian students and 48,72% South African students could solve the same problems correctly. Considering these results, the present study is aimed to explore the low performance of Indonesian students in fraction and to investigate its possible reasons.

THEORETICAL BACKGROUND

Fractions in TIMSS Mathematics – Fourth Grade

Fractions are a critical foundation for students because they are heavily used in various measurements and calculation [2]. Furthermore, fractions also serve as essential foundation to study algebra and to develop proportional reasoning. In TIMSS Mathematics – Fourth Grade, fractions are a topic area in the number content domain and takes part about 15% of the TIMSS test items. In TIMSS the topic of fraction covers two areas, i.e. the basic concept of fractions and the operations of fractions. The former deals with students' ability to "[r]ecognize fractions as parts of wholes, parts of a collection, or locations on number lines, and represent fractions using words, numbers, or models" [1; p. 15]. The operations of fractions include identifying equivalent simple fractions, comparing and ordering simple fractions, and performing addition and subtraction of simple fractions. Figure 1.a and Figure 1.b show examples of TIMSS test items which address the basic concepts of fractions, whereas Figure 2.a and Figure 2.b are examples of operations of fractions in TIMSS test items.
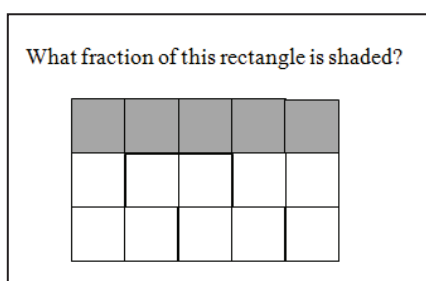
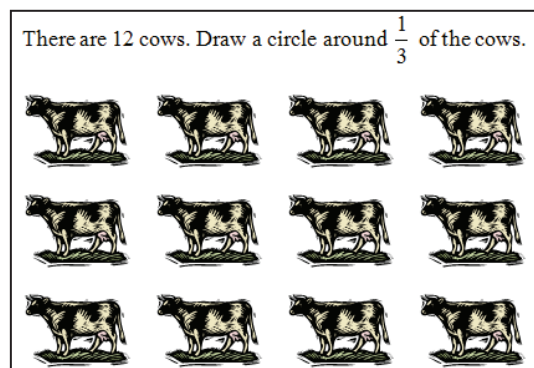

FIGURE 1a Fractions as parts of wholes

FIGURE 1b. Fractions as parts of a collection

FIGURE 2a. Identifying equivalent fractions and comparing fractions

FIGURE 2b. Addition and subtraction of fractions

Opportunity to Learn: Curriculum and Textbooks

In the First International Mathematics Study (FIMS), the International Association for the Evaluation of Educational Achievement (IEA) considered a so called 'opportunity to learn' which was defined as "whether or not […] students have had the opportunity to study a particular topic or learn how to solve a particular type of problem" [4; pp. 162-163]. This concept was used to find possible explanation for different mathematics achievement across participating countries. Interest in the concept of opportunity to learn is also because studies on this concept provide policymakers with information on the implementation of their policies, and at school level such studies provide information about the strengths and weaknesses of school practice and the appropriateness of the used materials or resources [5; 6].

Brewer and Stacz [7] distinguish three overlapping dimensions regarding opportunity to learn. The first dimension is the curriculum content which concerns the subjects and topics that have been taught to students. The second dimension is the instructional strategies which assesses whether students have experience with particular kind of tasks and solution processes. The third dimension refers to the instructional resources which covers instructional materials, such as textbooks. In TIMSS, the first dimension is examined through teacher questionnaire in which teachers are asked to indicate whether particular mathematical topics or kinds of problems have been learned by students. With regards to the third dimension, TIMSS analyzes textbooks by focusing on the amount of content covered in the textbooks and also the structure or the sequence of the content [8]. In addition to TIMSS study on textbooks, there a number of studies that revealed the relation between students' performance and the content of textbooks they read [9; 10; 11].

METHOD

The present study analyzed the data from TIMSS 2015 which included the test results and teachers' responses to the TIMSS Teacher Questionnaire. The data from 31 participating countries was used to portrait general information about students' performance and curriculum content. A further analysis was performed

for some low performing countries, i.e. Indonesia, Saudi Arabia, Kuwait, Jordan, and South Africa, and some top performing countries, i.e. South Korea and Japan. In addition to this data, electronic textbooks (Buku Sekolah Elektronik) for Grade 3 were also analyzed. In order to obtain information about the fourth graders' performance in fractions, the present study used descriptive statistics to analyze the test results. The Teacher Questionnaire data was included to find information about the topic of fractions in the curricula of Indonesia and benchmarking countries. In the Teacher Questionnaire for Fourth Grade, there are two items regarding the topic of fractions in the curriculum; i.e. "… when the students in this class have been taught … the concepts of fractions (fractions as parts of a whole or of a collection, or as a location on a number line)" and "… when the students in this class have been taught adding and subtracting with fractions, comparing and ordering fractions" Teachers were asked to choose: (a) 'mostly taught before this year' if the topics were in the curriculum before fourth grade; (b) 'mostly taught this year' if the topics were taught half this year but not yet completed; and (c) 'not yet taught or just introduced' if the topics are not in the curriculum. Descriptive statistics was performed to analyze teachers' responses to these items. For the last data – i.e. textbooks – a qualitative analysis was used to portrait how the textbooks present the topic of fractions.

RESULTS AND DISCUSSION

Indonesian Fourth Graders' Performance in Fractions

The analysis of students' responses to TIMSS test items that addressed fractions showed that Indonesian students underperformed students from Jordan, Saudi Arabia, South Africa, and Kuwait (see Table 1). This result indicates fractions are a big problem for most Indonesian fourth graders.

TABLE 1. Average Percentage of Correct Answer for Items About Fractions

TIMSS Mathematics – Fourth Grade			TIMSS Numeracy		
Country	TIMSS Score	Correct answer	Country	TIMSS Score	Correct answer
International	500	46,98%	International	500	47,33%
Indonesia	397	24,45%	Indonesia	397	42,67%
Saudi Arabia	383	29,42%	Jordan	388	46,76%
Kuwait	353	25,18%	South Africa	376	48,72%

When zooming on the TIMSS results per test item addressing fractions, it was obvious that for some items the percentage of correct answer of Indonesian students were remarkably lower than that of students from other countries (see Figure 3). For example, test item M07_04 in which only 6,8% Indonesian could solve the question correctly. This result was far below the percentage of correct answer of students from Saudi Arabia (53,3%), Kuwait (43,7%), and international average (55,3%). This item was about fractions as parts of a collection (see Figure 1.b). Unsatisfactory results were also obtained in TIMSS Numeracy which was actually easier than TIMSS Mathematics – Fourth Grade. Figure 4 shows that the performance of Indonesian fourth graders when solving questions about fractions was slightly lower than the performance of students from Jordan and South Africa.

As mentioned earlier, the topic of fractions in TIMSS covers areas, i.e. basic concepts of fractions and operations of fractions. This dichotomy led us to scrutinize students' performance in each of these two areas. Of 13 test items in TIMSS 2015, eight were about basic concepts of fractions and five were about operations of fractions. It was found that the percentage of correct answer given by Indonesian students for both areas were equally low. A different case was found in Saudi Arabia, Kuwait, and international average in which the percentage of correct answer for items addressing basic concepts of fractions was remarkably higher than the answer for items addressing operations of fractions. Such pattern was also found in the top performing countries such as South Korea and Japan (see Figure 5). This result highlights Indonesian students' low understanding of the basic concepts of fractions.
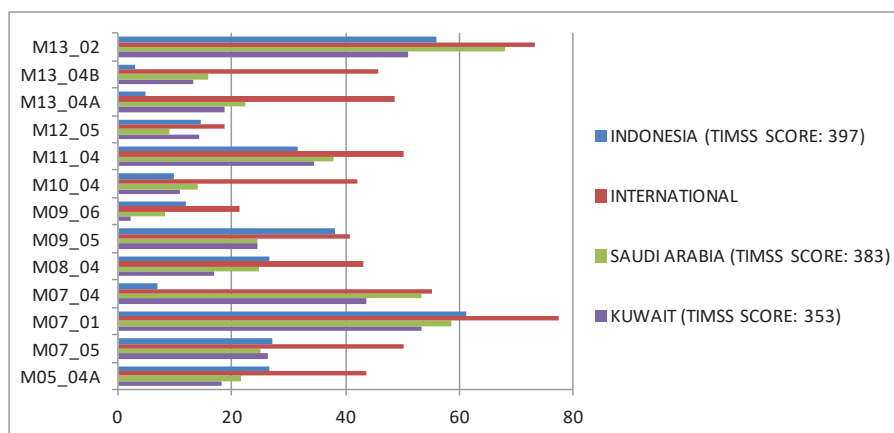
FIGURE 3. Percentage of Correct Answer for Items about Fractions in TIMSS Mathematics – Fourth Grade 2015
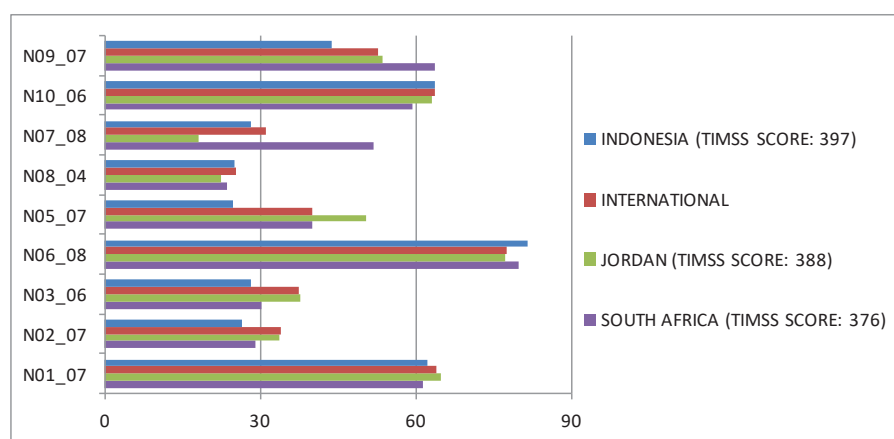

FIGURE 4. Percentage of correct answer for items about fractions in TIMSS Numeracy
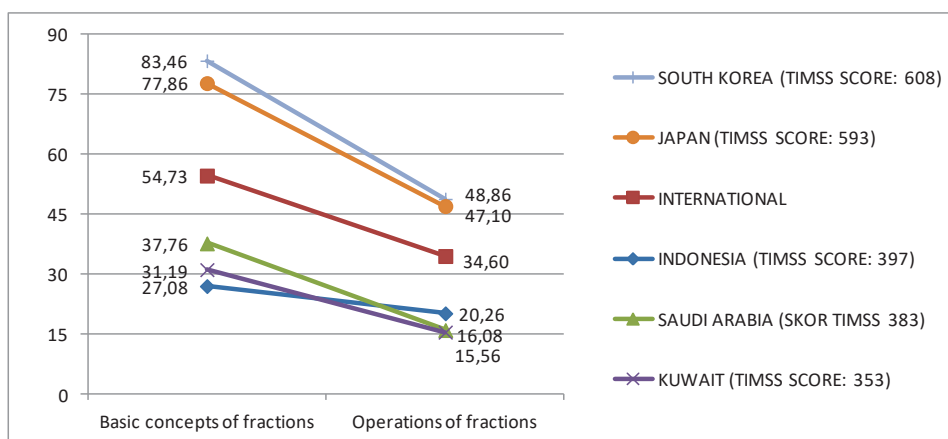

FIGURE 5. Results for Basic Concepts of Fractions and Operation of Fractions

Fractions in Indonesian Curriculum: A reflection of Teacher Survey

To find possible explanation for the low performance of Indonesian students in fractions, the present study investigated the content of the curriculum from the perspective of teachers' response to the Teacher Questionnaire. For this purpose, the present studies focused on two items in the Teacher Questionnaire for

Fourth Grade; i.e. "… when the students in this class have been taught … the concepts of fractions (fractions as parts of a whole or of a collection, or as a location on a number line)" and "… when the students in this class have been taught adding and subtracting with fractions, comparing and ordering fractions." Teachers' responses to the aforementioned two questionnaire items reveal that both basic concepts and operations of fractions have been taught since in the third grade in almost all participating countries. The proportion of basic concepts of fractions and operations of fractions in third grade varied among participating countries. The international average shows that 72% of topic of fractions in third grade was about basic concept of fractions and the remaining 28% was operations of fractions. It is interesting to see the relation between the proportions of these two areas of fractions with students' performance in fractions. Figure 6 shows the relation between the average percentage of correct answers for items addressing fractions and the difference between proportions of basic concepts and operations of fractions taught in the third grade (i.e. proportion of basic concepts – proportion of operation) for the majority of TIMSS participating countries. The higher the value on the horizontal axis means higher emphasize on the basic concepts of fractions in the third grade. The trendline on Figure 6 indicates a tendency that students in countries which in the third grade give more emphasis on basic concepts have higher performance in mathematics than their counterparts from other countries.
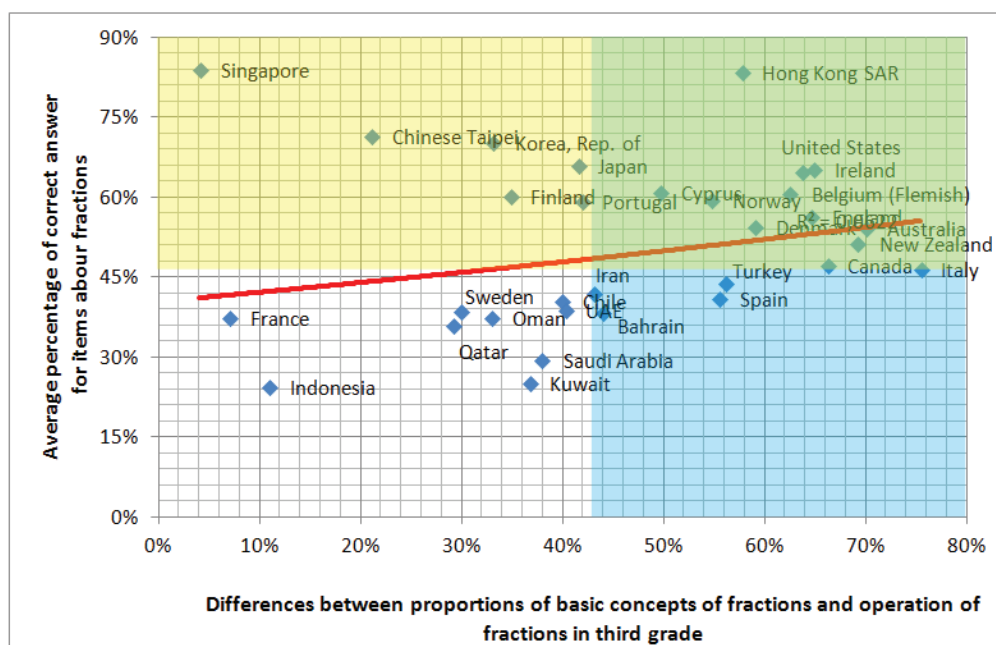

FIGURE 6. Relation between Students' Performance in Fractions and the Scope of Fractions Taught in Third Grade

Zooming in the abovementioned relationship on Indonesia and countries mentioned in Figure 5 (i.e. South Korea, Japan, Saudi Arabia, and Kuwait), it is found that third graders in Indonesia learn operation of fractions as much as basic concepts of fractions. A different situation was found in the other four countries which give more proportion for basic concepts of fractions than operation of fractions (see Figure 7). It might explain why students from these countries have better performance in basic concepts of fractions than in operation of fractions, whereas Indonesian students have low performance in both areas
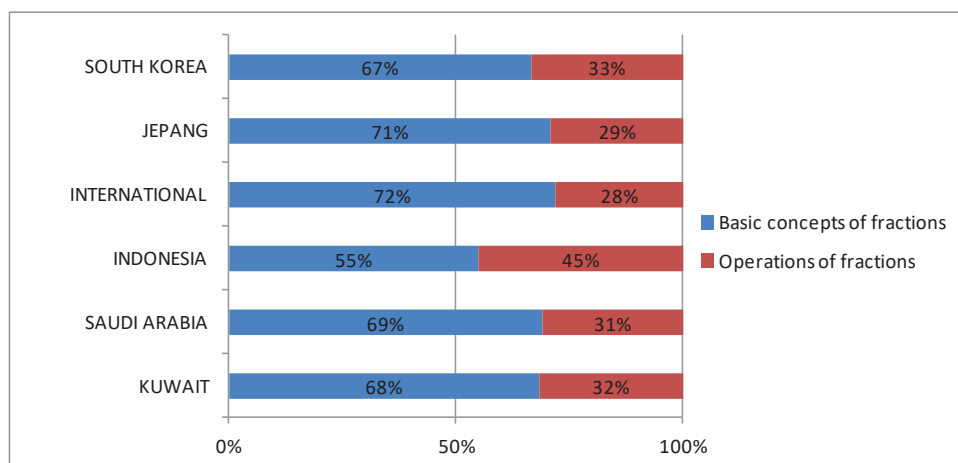
FIGURE 7. Topic of Fractions in Third Grade in Indonesia and Benchmarking Countries

Fractions in Indonesian Textbooks

In order to have a broader perspective of possible explanation for Indonesian fourth graders' low performance in fractions, Indonesian textbooks were examined. The results of textbook analysis show that Indonesian textbooks restricted the definition of fractions only as parts of wholes. An example of this definition in an Indonesian textbook can be seen in Figure 8. This restriction might contribute to the low understanding of Indonesian students about the basic concepts of fractions. As mentioned earlier, the percentage of correct answer of Indonesian students for tasks addressing fractions as parts of a collection was remarkably lower than that of other countries.
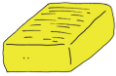
Textbook content	Translation
Satu tahu dinyatakan dalam lambang pecahan biasa $\frac{1}{1}$ dibaca satu per satu.	A tofu can be represented as a fraction $\frac{1}{1}$, which is read as 'one over one'
Satu tahu dipotong menjadi dua bagian sama besar dinyatakan dalam lambang pecahan biasa $\frac{1}{2}$ dibaca dua per dua.	If a tofu is cut into two equal pieces, then each piece can be represented as $\frac{1}{2}$, which is read as 'one over two'
Satu tahu dipotong menjadi tiga bagian sama besar dinyatakan dalam lambang pecahan biasa $\frac{1}{3}$ dibaca satu per tiga.	If a tofu is cut into three equal pieces, then each piece can be represented as $\frac{1}{3}$, which is read as 'one over three'
Satu tahu dipotong menjadi empat bagian sama besar dinyatakan dalam lambang pecahan biasa $\frac{1}{4}$ dibaca satu per empat.	If a tofu is cut into four equal pieces, then each piece can be represented as $\frac{1}{4}$, which is read as 'one over four'
Dayu memotong tahu menjadi 2 bagian sama besar. Satu bagian yang berwarna, dinyatakan dinyatakan dalam lambang pecahan biasa $\frac{1}{2}$. Jadi, $\frac{1}{2}$ adalah 1 bagian dari 2 bagian yang sama.	Dayu cuts a tofu into two equal pieces. The colored piece can be as $\frac{1}{2}$, which is read as 'one over two'. Therefore, $\frac{1}{2}$ is one part of two equal parts.

FIGURE 8. An example of definition of fractions in Indonesian textbook

In an addition to this restriction of the definition of fractions, when discussing fractions as parts of wholes Indonesian textbooks did not offer enough opportunity for students to do fair sharing by themselves. The

textbooks provided a whole which was already divided into several equal parts and only asked students to shade some parts that represented a certain fraction. Limited opportunity to do fair sharing might lead students to focus only on the number of shaded parts and ignore that all parts must be equal. At the end, it might to contribute to students' difficulties in solving question as shown in Figure 9. TIMSS results show that option C was the majority among incorrect responses of Indonesian students. It indicates that these students only focused on the number of the shaded areas.
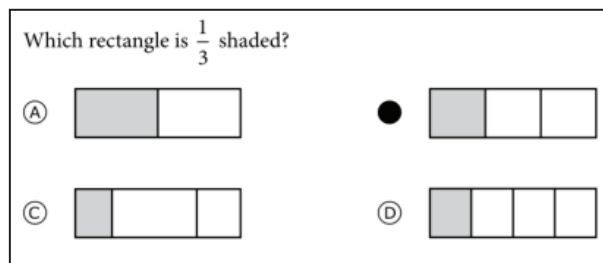

FIGURE 9. Fractions Represented as Shaded Areas

CONCLUSION

An analysis of the results of TIMSS Mathematics – Fourth Grade and TIMSS Numeracy reveals Indonesian fourth graders had low performance in fractions, even when being compared to students from countries with lower TIMSS total score. A further analysis shows that in particular for the understanding of basic concepts of fractions, Indonesian students remarkably lower than students from other countries. This low performance might be explained from two perspectives, i.e. the scope of fractions in Indonesian curriculum and in the textbooks. An analysis of TIMSS Teacher Questionnaire indicates that Indonesian curriculum gives low emphasis on the basic concepts of fractions and introduces basic operations of fractions quite early in grade three. A different situation was found in the curricula of other benchmarking countries which put more emphasis on the basic concepts of fractions. This claim is in agreement with recommendations of many researchers of fraction teaching and learning to give a greater emphasis to the meaning of fractions rather than rote procedures for working with fractions [2; 12]. Another possible explanation for Indonesian fourth graders' low performance in fraction is textbooks. Indonesian textbooks only provide one definition of fractions – i.e. fractions as parts of wholes – whereas TIMSS uses three definitions of fractions. This restriction of the definition of fractions might make students struggle with fractions because several studies reported that multiple meanings of fractions often confuse students [2]. Furthermore, Indonesian textbooks also give very limited opportunity for students to experience to do fair sharing by themselves.

Based on the results of the present study there are important points to consider regarding the teaching and learning of fractions. First, in early grades it is important to give more attention to the basic concepts of fractions because they serve as fundamental basis for students to learn fractions. Second, students need to learn and experience all definitions of fractions..

ACKNOWLEGMENT

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