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THE ROLE OF MANIPULATIVES USAGE IN MATHEMATICS LEARNING OF PRIMARY EDUCATION WITH SCIENTIFIC APPROACH TOWARDS THE STUDENTS' THINKING ABILITY

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Abstract: *Referring to the purpose of mathematics learning, the important aspect in mathematics learning is improving the students' problem solving ability. Meanwhile, problem solving in mathematics needs thinking ability. The learning required by the Indonesian curriculum is learning with scientific approach. The characteristics of scientific approach within learning can be seen by the utilization of appropriate manipulatives. The purpose of limited testing in this research is to describe the implementation of scientific approach principles within manipulative-assisted learning in primary education. The result of limited testing among the three types of learning shows a positive students' motivation (scored 78 of maximum 100) and the average of effectiviness score for the whole implementation of scientific approach is 75. The low effectiveness among the indicators of scientific approach implementation happened at the indicator of students asking, students asking started by teacher guidance, and students' opportunity to accommodate concepts-principles. Those indicators become the basic improvement and perfection of the manipulative product and its learning devices.*

Keywords: *mathematics manipulatives, scientific approach, students' thinking ability*

1. INTRODUCTION

Providing manipulatives in mathematics learning for primary education becomes one of important components in improving the quality of learning result. The manipulatives is one of the recommended media used for learning. One of the mainstay research products in the collaboration of the higher education and industry as part of the multi-years research is the prototype of manipulatives for mathematics learning in primary education (primary and secondary school). The manipulatives tested here is the solid shape manipulatives. Validation by experts including academics, practitionaire, and policy maker has been done and the

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result is valid (Hidayah, 2015). Various researches about the utilization of similar manipulatives suggest that it is effective to be used in mathematics learning. The obstacle to provide the high quality manipulatives for mathematics learning in the market is the one which become the foundation of this research. The analyisis result from the empirical testing in mathematics classroom is used to revise and to make perfection of the manipulative product and its utilization such that the final product of the research could give the real advantage for the sustainability of high quality mathematics learning and suitable with the characteristics of learning as required by the Indonesian 2013 Curriculum. One of the characteristics of the 2013 curriculum is the implementation of scientific approach. The indicator of scientific approach is the emerge of the following activities: observing, asking, trying, associating, and networking. According to Dyers, (2011) Tarmuchi, Mohamed & Ismail (2015) the children's creativity can be gained through scientific-approach-based learning.

2. LITERATURE REVIEW

The scientific approach is one of approaches of learning. It gives guidance to learn science since every teacher can motivate students to observe, to deliver question, to predict, to have an experiment, and to discuss their findings (Gerde, 2013). According to the Indonesian Minsitry of Education and Culture (Kemendikbud, 2013), the characteristics of scientific approach are as follows: (1) student centered, (2) learning to form students' self concept, (3) learning without verbalism, (4) learning gives chance to the students to assimilate and accommodate concepts, lawsand principles (5) learning triggers the improvement of students' thinking ability, (6) learning to motivate students to learn and to motivate teacher to teach, (7) learning gives chance to the students to train their communication ability, and (8) there is validation process towards concepts, laws, and principles constructed in the students' cognitive structure. The scientific approach elaborates the stages of exploration, elaboration, and confirmation, including the following activities: (1) **observing**, the relevant activities in observation heading include to observe, to read, to listen, to heed (with/without tools); (2)**asking**, the students deliver questions start from factual things to hypothesis, started by teacher guidance until becoming a habit; (3) **trying** or collecting information, the students determine the data of the question delivered, determine the data sources (objects, documents, experiment), and then collect the information needed; (4) **associating**, after collecting the data, the next steps to analyze the data in form of categorizing, defining the relation among data/category, and concluding the result of data analysis; (5) communicating, to re-deliver the result of conceptualization in a form of oral, writing, diagram, chart, picture, or the other media.

Krulik (1995) said that teacher has to combine problem solving and thinking in every mathematics classroom. Teacher has to be able to facilitate students such that the learning is effective at all level of students. The utilization of manipulatives in mathematics learning is expected to be able to assist teacher to facilitate and to provide stimuli for the students such that the students respond by showing activities of scientific approach.

Reasoning is part of thinking which is higher than recalling level. Reasoning includes basic thinking, critical thinking, and creative thinking. Krulik (1995) also said that problem solving and reasoning are the primary skills that our students must take with them when they leave our classrooms and enter the "real world".The basic thinking is explained by understanding of concepts dan recognizing a concept when it appears in a setting. Critical thinking is explained by examining, relating, and evaluating all aspects of a situation or problem; focusing on parts of situation or problem; gathering and organizing information; validating and analyzing information; remembering and associating previously learned information; determining reasonableness of an answer. Creative thinking is explained by original, effective, and produces a complex product; inventive. The scientific approach initially includes observing, asking, trying, associating, networking, and creating. However, the starting of implementation of 2013 curriculum leaves the level of creating to gain the more rational target to facilitate the students to be critical and creative.

Some supporting researches can be found as follows. Ojose (2009) researched about the effect of manipulative materials on mathematics achievement of first grade students, he shows that the interaction between mathematics instruction and manipulative use could increase the students achievement and manipulative have also been useful in making abstract ideas concrete learners and there by making for conceptual understanding. The importance of manipulative use also suggested by Kelly (2006). Preparing students to utilize concrete material and exploration of problem solving are oftenly abandoned, whereas it is one of important elements for the success of mathematics learning. We have to develop the higher order thinking and fluency as well as flexibility to the students, for instance, about the concept of number. This idea supports the implementation of manipulative-based problem solving in the classroom. Research about optimization of the utilization of environment and manipulative as learning sources conducted by Hidayah (2008) and suggest that the learning was joyfull and could develop the exploration ability very well, the exploration activity was 86,75% and the average of exploration of test result was 73,57. Besides, the result conducted by Hidayah and Sugiarto (2014) said that in order to facilitate students activity with observing, asking, collecting information, associating, and communicating, we need a set of productive question supported by manipulative.

3. METHOD

This research is part of the stages of Research and Development, which is the empirical testing stage (Gall *et al*., 2003, Sugiyono, 2010). This research used experimental design of one-shot case study (Sugiyono, 2010). The research was conducted at VIII-B grade students of SMP Negeri 13 Semarang, it is one of state junior high schools in Semarang, Indonesia. According to the purpose of research, the class was intervened by using manipulative-assisted scientific approach learning. The manipulative used based on the current material taught at school, namely the solid shape. The manipulative included: the manipulative of solid frame, surface area, and volume of cuboid, cube, prism, and pyramid. Beside observing the practicality and effectiveness of the utilization of manipulatives, we also observe the obstacle in order to formulize the further improvement of the manipulatives. The practicality of the manipulative was shown by the students response and the average score of students motivation towards the learning. While the effectiveness of the manipulative was shown by suitability of the learning implementation with the criteria of 2013 curriculum. In order to determine the effectiveness of manipulative, we set the ideal score of the whole and per item of the observation instrument towards the implementation of mathematics learning using scientific approach and manipulatives (Sugiyono, 2010).

The ideal score of the learning implementation as a whole is $4 \times 21 \times 3 = 252$ (4 is the highest score, 21 is the number of indicator, and 3 is the number of observer). Then the effectiveness is calculated by using formula:

$$\frac{\text{sum of score from all observe}}{\text{whole idea score}} \times 100\%$$

while the effectiveness per indicator is calculated by using formula:

$$\frac{\text{sum of score from all observe}}{\text{whole idea score}} \times 100\%$$

Besides, the effectiveness of manipulatives within learning towards the scientific approach principles was measured by the improvement of the average result of formative test 1, 2, and 3; and the completeness of learning of the final test in the material of solid shape. The supporting data was presented in narrative way in order to get insight into the obstacle or disadvantage observed during the learning activities. The improvement of formative test result was calculated by normalized gain formula or the g-factor or Hake factor (Hake, 1999; Heckker, 2004).

This limited testing research of product has been initialized by development of learning devices. The learning model is suitable with the teacher's design, it is integrated with scientific approach and manipulative use, it is also equipped with student worksheet and assignment sheet to support the use of manipulative. Besides, the development of learning scenario referred to the guideline of manipulative manual and is equipped by set of productive questions which guide students to think and to find mathematics concepts/principles they learn.

4. RESULT

The students' response towards the implementation of learning with scientific approach and manipulative use said that it was "joyful" to join the learning (87%). The reason of that was "because it use manipulatives" 73%, "because the teacher is interesting" 77%, "we got many new experiences" 80%, and because "students are active" 67%. The response of students that this learning shall be continued to the next material is 93%, the material is easy to understand 60%. While the average score of students' motivation to join the learning is 3.1 of the maximum score 4 or 78 of the maximum score 100.

Table 1.
Percentage of students' response as the reason why they say it is joyful to join learning with scientific approach and manipulative use

Students' response	*Percentage*
(a) using manipulatives	75
(b) teacher is interesting	68
(c) many chances to deliver opinion	33
(d) using worksheet and assignment sheet (not much taking note)	28
(e) no need to imagine	77

The teacher's response was positive and he said that the use of manipulative in scientific approach learning made the learning was more interesting and easy. Nevertheless, teacher feel that the use of manipulative has not been optimized yet because the magnetic board was narrow and the set of manipulative should be more than one to enable students to work in group. The effectiveness of the manipulative-assisted learning towards the criteria of scientific approach with the ideal score above 75 at the learning 1, 2, and 3 get score respectively 67%, 71%, and 62%. It means that there are some indicators which have not been suitable nor been implemented yet. The indicators of scientific approach principles which were not effective at the learning 1, 2, and 3 were presented at the Table 2 as follows.

Table 2.
The ineffectiveness of the manipulative use towards the implementation of indicators of scientific approach learning principles

Indicator of learning principles by using scientific approach	*The effectiveness*
Students ask from the factual things to the hypothesis things	25
Students' activities in asking questions are started from teacher guidance until become independence	25
Learning gives chance to the students to accommodate concepts, laws, and principles	25

Beside the ineffectiveness towards the three indicators mentioned above, the ineffectiveness towards the other indicators also emerged during the third learning. The indicators are "Students discuss before, in the middle, or after the presentation" (25) and "Students deliver their ideas about the material orally (through question and answer session) or written (through worksheet). It happened because the teacher did not use any worksheet. The effectiveness score from the learning 1, 2, 3 are respectively 76, 86, and 70 from the minimum score 75. The final test result of learning 1, 2, 3 are respectively 51, 65, and 70. The normalized gain value from learning 1 to learning 2 is 0.286 (low), and from learning 2 to learning 3 is 0.143 (low). The final test score including material taught in the learning 1, 2, 3 is 77 with deviation standard 13, maximum 100, and minimum 50. The percentage of the students completing their learning (scored ≥ 71) is 66%. The value of 71 is got from the standard of minimum achievement for mathematics subject determined by the school.The learning result is said complete when 75% of the students get mark ≥ 71. Thus, the final test in this empirical testing at the material of solid shape has not reached the classical mastery learning.

5. DISCUSSION & CONCLUSION

Based on observations and the results of the data analysis of the implementation of learning 1,2, and 3, the response of students and teachers were positive.Then, it can be said that the use of manipulatives to support the implementation of learning with scientific approach is as expected by the government. However, to enhance the presence of manipulative, so as to support the implementation of optimal learning it is necessary to improve the students' responses.Some of the reasons why the students' responses expressed pleasure in learning is still at low percentagepossibly because the students have not felt that these activities are dominantly useful and meaningful in the learning process. At the time of the working group, some students in the group is still working on their own, do not use manipulatives that have been provided to do the student worksheets. Students did not focus on the activities of students' worksheets. The final result of

student worksheet is predicted not derived from the thought process that has been conditioned in the worksheet, but they get from students' books. Thus the purpose of the use of manpulative as a tool for students in group work with worksheets for students in concepts / principles of mathematics has not been achieved as expected. Basically, students work by utilizing the worksheetby means of work inventions.Worksheet is a help or guidance teacher in written form that encourages students to discover concepts and ideas and develop aspects of exploration and experimentation of knowledge (Kyriazis, 2009). Learning becomes meaningless. Students are not actively construct mathematical concepts or principles learned in their mind. Any knowledge or ability can only be obtained or controlled by a person if the person is actively construct knowledge or ability in his mind (Zevenbergen& Wright, 2004). It is said also by Joolingen (1999) that students can build their own knowledge when students can learn to design their own experiments and make inferences rules that have been obtained. To optimize the implementation of learning, not only to enhance and complement the manipulative teaching aids used in teaching, but also the design of an enhanced learning more thorough and more operational, fully and clearly what and how teachers and students must do during the learning.The use of manipulative should be integrated in the learning. The use of manipulative are equipped with the appropriate worksheets contain a series of questions or instructions that must be answered or performed by the students and the students do it right, then learning becomes meaningful. Manipulative and worksheets have been prepared, but the use of manipulativein learning 1 and 2 is not optimal, particularly on learning 1 and 2. In the first study, students did the worksheet without accompanied by manipulative. While in learning 2, students were not given the opportunity to experiment and work on worksheets in the group. Demonstration activities invented the concept of volume is dominated by the teacher. From these results, in order to improve the development of practical manipulative use, then the panel board as a complement to the use of manipulative in the learning expanded with 2 times larger (160 x 120) cm; and prepared manipulatives for group work (with a smaller size than manipulative for classical use). While the other thing that must be considered in the learning, the teacher should explain to students what a student must do before working on worksheets in the group.

Based on the results of the analysis of the effectiveness of the use of manipulative in the learning with scientific approach, learning 1 and 2 has reached the effectiveness as a whole, while the learning 3 is under the minimum scoreof the overall effectiveness. In order to search for possible causes, so it can be used as a basis to make improvements,it can be reviewed on the effectiveness of the indicator implementation of learning with scientific approach. Above, we have explained that there are six indicators that have low effectiveness scores that occurred in all three learning.The questioning activity is the important activity

in implementing the inquiry based learning. It enable teacher to earn information from students, informing what have been known by students, and driving the students' attention toward what they have not known yet. The importance of good questions is also asserted by Orton (1991), Rabahi, Yusof & Awang (2016) by saying that good questions are important in facilitating learning.

During the learning, students did not ask factualquestions, or the hypotheticalquestion, either. Likewise, the students did not undertake ask that begins from the guidance of teachers to independently. Teachers give a stimulus to students so that students ask the question with the motivation "I will give you points when you ask," however the students respond by asking low quality questions. Asking activities spontaneously is not familiar to the students. Productive series of questions to provoke students to think has been made in the guide manipulative use as the result of the first year of research products. But it is not completely appear in classroom learning trials. Teachers are not doing right. He did not use a series of productive questions appropriately.The consequences are that the students did not get the opportunity to accommodate the concepts, laws, and principles are being learned, which also means students do not perform perfectly reasoning (basic, critical, and creative thinking).Meanwhile, student activities to do recall activity emerged because the habit of teacher to do apperception. In order to increase the activity of students' thinking in the learning, learning strategies need to be considered and chosen accordingly so as to make the students think. Kitchens, Barber & Barber (1991) said in Aizikovitsh-Udi (2011) that matching teaching style to learning and thinking styles will increase academic achievement and the make the teaching and learning process an enjoyable experience. As a next improvement of the implementation, in addition, improvements in the props manipulative, completeness, and devices, the readiness of teachers should also be considered. As presented by Ye (2015) that education is the foundation of a country to become rich and powerful. Teachers are the most important part ofthe education system, teacher emotion is an educational tool that directly affect students' physical and mental.

The learning 2 gives quite high score of effectiveness of the use of manipulative towardsthe implementation of scientific approach which is 86. Teacher was in a good condition while doing a demonstration in front of the class, a series of questions, and students complete worksheets by manipulating the manipulative. It shows that teachercould influence the emotions of students, and generate students' creativity in making nets geometry, one example is presented in Figure 1.

Figure 1. Students activities in learning with high effectiveness

Sayadian (2015) said that focusing on the emotions and thoughts of students is believed to train students not only in the field of student learning, but also help students to acquire essential life skills such as creativity. The skills are necessary for students to develop a strong personality andeffective communication. In order to make the implementation of scientific approach better, then the object observed should be correct, a series of questions as stimuli for students to think should be standardized and complete. It is expected that learning will give students experiences to collect or to receive information that is complete and the students can perform and complete reasoning correctly. We also provide example of how students use manipulative with a series of productive questions until they find concepts as presented in the appendix.

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Appendix

Sample of manipulative use of cuboid volume with sets of productive questions

1. **Manipulative: Supporting tools**: table, Manipulative Fig-2.1

   Manipulative of Cuboid Volume (Fig-2.1)

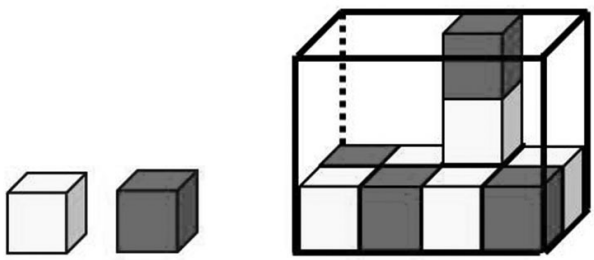

Figure 2.1

2. **Purpose of learning:** By using scientific approach and assisted by manipulative Fig-2.1, students can find the formula of cuboid volume.

3. **Learning activities:**

3.1 *Activities to recall the prerequisite knowledge*

1. Teacher paste the model of rectangle in the magnetic board as shown at Fig-2.2.(a), teacher asks:
   - What is the shape of this model? (*rectangle*)
   - What is the length? (*3 unit*)
   - What is the width? (*2 unit*)
   - What is the area? (3 x 2 unit)

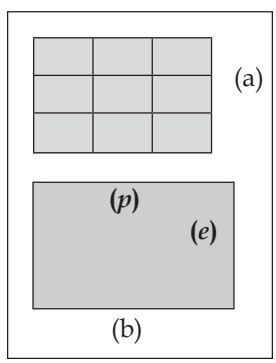

Figure 2.2

2. Teacher paste the model of rectangle in the magnetic board as shown at Fig-2.2.(b), teacher asks:
   (a) What is the shape of this model? (*rectangle*)
      - What is the length? (*p*)
      - What is the width? (*l*)
      - What is the area? (*p x l*)
3. Teacher puts the model of cuboid on the table as shown at Figure 2.3, teacher asks:

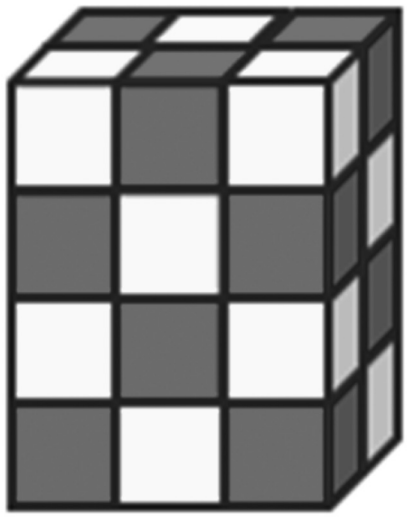

Figure 2.3

   (a) What is the shape of this model? (*cuboid)*
   (b) If the base of the cuboid is the lower face, then:
      - What is the length? (*3 unit*)
      - What is the width? (*2 unit*)
      - What is the height? (*4 unit*)
   (c) If the base of the cuboid is the front face, then:
      - What is the length? (*3 unit*)
      - What is the width? (*4 unit*)
      - What is the height? (*2 unit*)

3.2 *Activities to find concept/principle*

Activity 1

1. Teacher shows the cuboid model with position as shown in Fig-2.4.(i), and asks the students as follows:

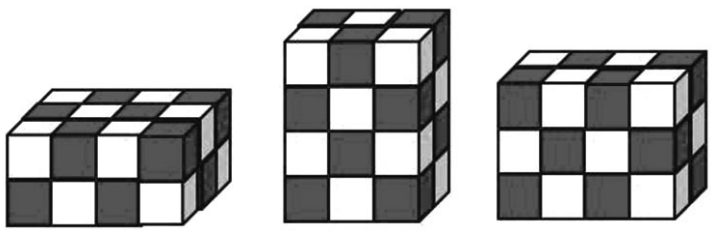

Figure 2.4. (i), (ii), (iii)

- What is the shape of this model? (*Cuboid*)
- What is the length? (*4 unit*)
- What is the width? (*3 unit*)
- What is the height? (*2 unit*)
- What is the volume? (*24 unit*)
- How is the appropriate way to calculate the volume of this cuboid? (*4 unit x 3 unit x 2 unit*)

2. Teacher shows the cuboid model with position as shown in Fig-2.4.(ii), and asks the students as follows:

- What is the shape of this model? (*Cuboid*)
- What is the length? (*3 unit*)
- What is the width? (*2 unit*)
- What is the height? (4*unit*)
- What is the volume? (*24 unit*)
- How is the appropriate way to calculate the volume of this cuboid? (3unit x 2 unit x 4 unit)

3. Teacher shows the cuboid model with position as shown in Fig-2.4.(iii), and asks the students as follows:

- What is the shape of this model? (*Cuboid*)
- What is the length? (*4 unit*)
- What is the width? (*2 unit*)
- What is the height? (*3 unit*)
- What is the volume? (*24 unit*)

- How is the appropriate way to calculate the volume of this cuboid? (*4 unit x 2 unit x 3 unit*)

Activity 2

1. Given a cuboid as shown at the Figure 2.5. the length is 10, the width is 8, andthe height is 6, then:

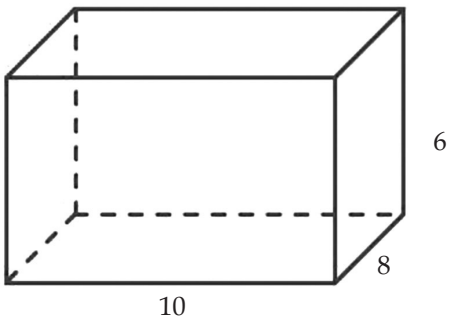

Figure 2.5.

- What is the volume? (*10 x 8 x 6*)

3.3 *Conclusion activity*

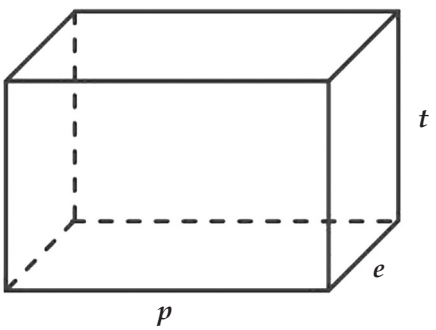

Figure 2.6.

Given a cuboid, with length p, width l, and height t, and volume V, then:

V = … × … × …

or

V = base area × height

Note: the base is rectangle