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" The Global challenges on the development and the education of mathematics and science "

3rd ICRIEMS

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The Global Challenges on The Development and
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- Mathematics & Mathematics Education
- Physics & Physics Education
- Chemistry & Chemistry Education
- Biology & Biology Education
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Preface

Bless upon God Almighty such that this proceeding on 3rd International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS) may be compiled according to the schedule provided by the organizing committee. All of the articles in this proceeding are obtained by selection process by the reviewer team and have already been presented in the Conference on 16 – 17 May 2016 in the Faculty of Mathematics and Natural Sciences, Yogyakarta State University. This proceeding comprises 9 fields, that is mathematics, mathematics education, physics, physics education, chemistry, chemistry education, biology, biology education, and science education.

The theme of this 3rd ICRIEMS is '*The Global Challenges on The Development and The Education of Mathematics and Science*'. The main articles in this conference are given by six keynote speakers, which are Prof. Allen Price, Ph.D (Emmanuel College Boston USA), Ana R. Otero, Ph.D (Emmanuel College Boston USA), Dr. Michiel Doorman (Utrecht University, Netherlands), Prof. Dr. Marsigit, M.A (Yogyakarta State University), Asst. Prof. Dr. Warakorn Limbut (Prince of Songkla University, Thailand), and Prof. Dr. Rosly Jaafar (Universiti Pendidikan Sutan Idris, Malaysia). Besides the keynote and invited speakers, there are also parallel articles that presented the latest research results in the field of mathematics and sciences, and the education. These parallel session speakers come from researchers from Indonesia and abroad.

Hopefully, this proceeding may contribute in disseminating research results and studies in the field of Mathematics and Sciences and the Education such that they are accessible by many people and useful for the Nation Building.

Yogyakarta, May 2016

The Editor Team

Forewords From The Head Of Committee

Assalamu'alaikum warahmatullahi wabarakatuh

May peace and God's blessings be upon us all

First of all, allow me to thanks to God, Allah SWT, who has been giving us blessing and mercies so we can join this conference. Ladies and Gentlemen, it is my great honor to welcome you to Indonesia, a unique country which has more than 17,000 islands, more than 1,300 ethnic groups, and more than 700 local languages, and I am also very happy to welcome you to Yogyakarta, the city of education, culture, tourism, and a miniature of Indonesia. We wish you be happy and comfortable in attending the conference in this city.

The third International Conference on Research, Implementation, and Education of Mathematics and Science (ICRIEMS 3rd) 2016 is organized by the Faculty of Mathematics and Science, State University of Yogyakarta. In this year, theme of the conference is : The Global Challenges on The Development and The Education of Mathematics and Science. This conference are dedicated to the 52nd anniversary of Yogyakarta State University and to face challenges of Asean Economic Community in 2016.

This conference facilitates academics, researchers and educators to publish and disseminate their research in the fields of pure, application and education of Science and Mathematics. Furthermore, the purposes of the conference are to establish interaction, communication, and cooperation among academics, researchers and educators at an international level.

On behalf of the committee of this conference, I would like to express our highest appreciation and gratitude to the keynote speakers, including:

1. Allen Price, Ph.D. (Associate Professor of Emmanuel College, Boston USA)
2. Ana R. Otero, Ph.D. (Emmanuel College, Boston USA)
3. Dr. L.M. (Michiel) Doorman (Associate Professor of Utrecht University, Netherland)
4. Prof. Dr. Marsigit, MA. (FMIPA, Universitas Negeri Yogyakarta)
5. Asst. Prof. Dr. Warakorn Limbut (Faculty of Science, Prince of Songkla University, Thailand)
6. Prof. Dr. Rosly Jaafar (Faculty of Physics, Universiti Pendidikan Sultan Idris, Malaysia)

Furthermore, we inform you that the papers presented in this conference are about 200 papers from 302 applicants, who come from various countries and various provinces throughout Indonesia. Therefore, I would like to give my appreciation and many thanks to the presenters and participants who have been actively involved in this seminar.

Finally, I would like to thank the committee members who have been working very hard since half a year ago to ensure the success of the conference. However, if you find any shortcomings and inconveniences in this conference, please forgive us. We would very

happy to receive your suggestions for improvement in the next conference. Thank you very much.

Wassalamu'alaikum warohmatullahi wabarakatuh.

Yogyakarta, May 2016

Dr. Warsono, M.Si.

Forewords From The Dean Of Faculty Of Mathematics And Sciences, Yogyakarta State University

Assalamu'alaikum warahmatullahi wabarakatuh. My greetings for all of you. May peace and God's blessings be upon us all.

On behalf of the Organizing Committee, first of all allow me to extend my warmest greeting and welcome to the International Conference on Research, Implementation, and Education of Mathematics and Sciences, the third to be held by the Faculty of Mathematics and Science, State University of Yogyakarta, one of the excellent and qualified education universities in Indonesia. This conference is also celebrate the 52th Anniversary of State University of Yogyakarta.

This conference proudly presents keynote speeches by six excellent academics, these are: Allen Price, Ph.D., Ana R. Otero, Ph.D., Dr. Michiel Doorman, Prof. Dr. Marsigit, MA., Asst. Prof. Dr. Warakorn Limbut, and Prof. Dr. Rosly Jaafar, and around 200 regular speakers.

The advancement of a nation will be achieved if education becomes a priority and firmly supported by the development of technology. Furthermore, the development of technology could be obtained if it is supported by the improvement of basic knowledge such as mathematics, physics, chemistry, and biology. The empowerment of this fundamental knowledge may be achieved by conducting research which is then implemented in developing the technology and the learning process in schools and universities.

This international conference is aimed to gather researchers, educators, policy makers, and practitioners to share their critical thinking and research outcomes. Moreover, through this conference it is expected that we keep updated with new knowledge upon recent innovative issues and findings on the development and the education of mathematics and science, which is in accord with the theme of the conference this year. All material of the conference which are compiled in the abstract book and proceedings can be useful for our reference in the near future.

This conference will be far from success and could not be accomplished without the support from various parties. So let me extend my deepest gratitude and highest appreciation to all committee members who have done an excellent job in organizing this conference. I would also like to thank each of the participants for attending our conference and bringing with you your expertise to our gathering. Should you find any inconveniences and shortcomings, please accept our sincere apologies.

To conclude, let me wish you fruitful discussion and a very pleasant stay in Yogyakarta.

Wa'alaikumsalam warahmatullahi wabarakatuh

Yogyakarta, May 2016
Dean Faculty of Mathematics and Science
Yogyakarta State University

Dr. Hartono, M.Si.

Accomplishing Mathematics Problems Using *Outside The Box* Thinking Phase

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Abstract **–** Completion of math assignment is an important part of learning mathematics. However, in practice, students often do it in a way that is not creative (monotone). In other words, students are not able to think outside the box. This research described the process of students' thinking outside the box when they completed a math assignment using outside the box thinking phase. Outside the box thinking phase in this research included exploration, idea generated and justification. This research is important for educators to make thinking *outside the box* as the information input about the characteristics of students' thinking. The research instruments that had been validated by expert *validator* were given to the subject of research to be completed. To obtain accurate data, the subjects of the research accomplished it using think aloud technique. The subject of research explored the problem to get an idea of the problem situation. In this case the subject used logical reasoning in order to obtain an idea of different solution. The research subjects used fractions to strengthen the mathematical argument. The conceptual component of cognitive function happened was analyzing-integrating. Analyzing-integrating is the cognitive functions related to the quantity of a concept.

Keywords: *mathematical assignment, phase, outside the box thinking*

I. INTRODUCTION

Mathematical tasks completion does not stop at just getting the result but it also needs to pay attention to the process of accomplishing them that brings creativity of students. "Working on mathematical tasks may influence not only the mathematical content that is learned [1]". Creative behavior of students can be seen from the way the students argue/mathematical reasoning toward the completion of the math task generated. In generating different ideas on task completion, the students are given the opportunity to explore creatively so it is expected later the student will have autonomy and trust and they no longer use the standard thinking pattern (commonly thinking), that is pattern of thinking that only uses the basic algorithm skill.

"Reference [2] says creative thinking as *"out of the box thinking"* or *"outside the box thinking"*, which is a way of thinking "out" of the natural way of thinking *(get out of out our own box)."* Mental *"box"* is defined as the restriction created by people for themselves. The human brain has an efficient way of working. In other words the brain develops thinking patterns that recur every day, so it evolves into a "monotonous *(default)"* mental. Therefore, when brain faces a decision or a challenge, then it will easily estimate the limits of perspective that can be done. It means "monotonous" mental sometimes affects all activities undertaken. The existence of "monotonous" mental sometimes create a zone of "happy *(*comfortable*)"* which leads to a reluctance to upgrade their quality.

"Reference [3] describes the definition of *"thinking outside the box is generally associated with innovation and problem solving in business and management".*" Thinking *outside the box* is a term used to denote the level of thinking that is higher, that is, when the quality of task solution or completion idea is substandard and the solution has not been found. "Thinking outside the box (thinking out of the box or thinking beyond the box) is a metaphor that means to think differently, unconventionally, or from a new perspective. This phrase often refers to novel or creative thinking" [4]. Thinking *outside the box* associates with a willingness to get out of a happy *(*comfort*)* condition (zone) psychologically, open new perspectives toward the task, and the willingness (challenged) to explore. Therefore, this research is intended to describe the phases of thinking outside the box students in solving mathematical tasks. Stages or phases of thinking *outside the box* show the characteristics of the students to think outside the box to produce a different solution.

This research is important to know the characteristics of thinking *outside the box* in solving mathematical tasks through the behavior that can be observed. The activity of students' thinking *outside the box* is a thinking orientation that is "potentially" in the future. This is because thinking *outside the box* is a part of creativity, and creativity itself is a part of self-actualization at the highest level of Maslow's hierarchy of human needs. In addition, the research of thinking outside the box can be a contribution to enrich the knowledge of the thinking process, especially in mathematics.

II. LITERATURE REVIEW

Creativity based on the investment theory [5] contains six interrelated components namely intellectual abilities, knowledge, styles of thinking, personality, motivation and environment. Intellectual skills include (a) synthetic ability that is the ability to see the problem in a new way, out of the boundaries of conventional thinking; (b) analytical ability that is the ability to distinguish useful ideas which could be studied further than the idea that is less potential; and (c) practical-contextual ability that is the ability to convince others about the value of the ideas obtained. To be creative, one must generate new ideas, analyze the idea and present them to others.

"Creativity is the ability to bring ideas or works of art that are new, surprising and valuable" [6]. "Creativity involves the generation of ideas or products that are original, valuable or useful" [7]. Creativity associates with interesting and unimaginable previously new ideas. "For many there is an echo here of the intuition that "thinking outside the box" can be more creative than "thinking inside the box" [8]. It requires a more creative style of thinking that is thinking outside the box.

Thinking outside the box is different from lateral thinking [3]. Thinking outside the box is a linear way of thinking while lateral thinking does not create a new idea in a linear way but it finds in the "deviant" way. To be able to think outside the box, one must leave the comfortable zone psychologically (common routines), be opened with a new perspective toward a task, and bold (interested) in facing challenges. In addition, people who think outside the box should discard the character rigid, high personal egoism, and be able to manage emotions well.

Various models of problem solving are proposed by several researchers, including [9] with his famous completion stages that are widely used by other researchers. They are understanding the problem, divising a plan, carrying out the plan, and looking back. Problem solving in thinking outside the box is the problem solving that does not restrict students to explore the problem and to use the right strategy (uncommon ways) to produce different solutions. Thinking outside the box in solving mathematical tasks are through three phases or stages namely exploration, ideas generated and justification. Exploration phase has two criteria namely problem exploration and interpretation (mathematical interpretation). In interpreting a math assignment, students use the prerequisite knowledge previously possessed. The phase of ideas formation (ideas generated) contains two criteria, namely conjecture and representation. In making conjecture, the resulted solution strategy is different solutions strategy while justification phase contains the criteria namely justification. Justification toward the solution of mathematical tasks is reviewed through the logic and accuracy of students in completing the tasks. The process of settlement which is logical and right shows the understanding depth of the mathematical concepts that have been taught.

III. RESEARCH METHODS

This research is a qualitative research using Grounded Theory Approach. The purpose of grounded theory approach is data theorization that is the research does not start from a theory or to test the theory, but it starts from the data towards a theory. Based on the schedule agreed upon, the researcher gave a math assignment or task to the research subjects to be completed. The researcher used think alouds technique, the researcher observed the research subjects when completing the math assignment, and recorded all the activities of research subjects by using a digital camera. The observation result was not only in the form mathematical tasks completion but also in the form of moving images recording (video) of the students when they did the math task completion activities. To complete the observed data, the researcher conducted semi-structured interviews with a purpose to deepen the process of students' thinking outside the box.

At this phase of data analysis, the researcher conducted a series of activities including: (1) transcribing verbal data namely data obtained from think alouds and semi-structured interviews; (2) studying all data both verbal data and field notes; (3) reducing the data to create abstractions; (4) arranging and coding the based on the stages or phases that have been designed, namely the exploration, idea generated and justification; (5) drawing conclusions about the process of students' thinking outside the box in solving a math assignment using the exploration stage, idea generated, and justification.

IV. FINDINGS AND DISCUSSION

The research subject was asked to work on the instrument using the think alouds. The Subject wrote down the steps of completion while speaking, told everything he was thinking dealing with the completion steps that he wrote. The subject was very cooperative, and he had no difficulty in communicating with the researcher to communicate the results of the work. The subject was very confident, as seen from the loud noise sounded when he did think alouds. The subject provided two completion ways. In exploration phase (exploration), the subject understood the problem by formulating the information on the task (what is known?) and the objective which would be reached (what was asked?), and the subject read the questions aloud:

> Here known Iswanto only needs 5 tin cans to make another fully filled. All empty cans are removed. It means the five cans are used to fill $\frac{1}{5}$ part of the other cans. Here Iswanto needs 5 cans to fill all the remaining cans. Then the $\frac{1}{5}$ is the part that is not filled yet.

Based on the result of transcript, the problem situation on the mathematical task is understood by the subject that the content of tin cans was completely used to fill $\frac{1}{5}$ part of the other cans. The subject also underlined the sentence that he considered important (sentences that provided information) as Fig. 1 below. The underline shown by the subject showed that the subjects marked the important data which were known, identified the problem and tried to interpret them.

Petunjuk Soal: Selesaikan soal cerita berikut dengan menggunakan banyak cara (minimal dua cara) !

Iswanto adalah pengusaha susu kedelai. Suatu hari Iswanto menuangkan 60 liter susu kedelai seluruhnya ke dalam kaleng-kaleng dengan volume yang sama. Ternyata isi di dalam masing-masing kaleng belum penuh. Iswanto menginginkan kaleng-kaleng tersebut terisi penuh, sehingga Iswanto mengambil beberapa kaleng dan menuangkan isinya pada kaleng-kaleng yang lain. Iswanto hanya membutuhkan 5 kaleng untuk menjadikan kaleng yang lain terisi penuh. Kelima kaleng yang telah kosong selanjutnya disingkirkan.

Ternyata isi masing-masing kaleng yang ada sekarang bertambah tepat $\frac{1}{5}$ dari isi kaleng semula. Tentukan banyak kaleng sebelum pengambilan !

FIGURE 1. SUBJECT UNDERLINED THE SENTENCES THAT SHE CONSIDERED IMPORTANT

In Fig. 1, the Subject underlined two sentences: (1) Iswanto only needs 5 tin cans to make the other cans fully filled; and (2) the contents of each tin now exactly added $\frac{1}{5}$ more than before. However, the subject did not underline the objective (what is asked?). Subject interpreted the problem by considering $\frac{1}{5}$ part of each other cans was not filled yet, as written by the subject in Fig. 2 below. In Fig. 2, the subject wrote down the results of the interpretation in two sentences: (1) 5 cans for all cans; and (2) $\frac{1}{5}$ part of cans were not filled. The results of this interpretation were the description of a problem situation by Subject and designing a plan of the problem solution.

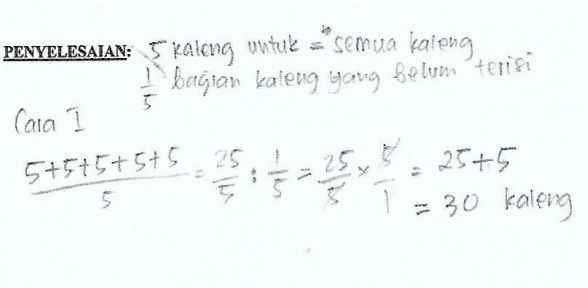

FIGURE 2. THE INTERPRETATION OF SUBJECT

At the phase of forming ideas (*ideas generated*), the subject attempted to purse the problem and found the core of the problem. The core of the problem in the question was that soy milk in the five tin cans was

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poured in the other cans exactly $\frac{1}{5}$ each. To write the steps of the solution, subject recalled about how to convert integers into fractions and the concept of operations on fractions. Further subject implemented the completion strategy (a strategy to determine the appropriate notation) as shown in Fig. 2 While recalling the concept of fractions, Subject wrote 5 in the form of a fraction $\frac{5+5+5+5+5}{5} = \frac{25}{5}$. This was done with the intention to make it easier to perform operations on the division of fractions (equated denominator 5). The next process was dividing $\frac{25}{5}$ by $\frac{1}{5}$ (Subject explained the reason, "because five tin cans are used for $\frac{1}{5}$ of the other tin cans, then it is divided by $\frac{1}{5}$"), $\frac{5+5+5+5+5}{5} = \frac{25}{5} : \frac{1}{5} = \frac{25}{5} \times \frac{5}{1} = 25 + 5 = 30$. Subject did not understand yet the concept of equation as $\frac{5+5+5+5+5}{5} = \frac{25}{5} : \frac{1}{5}$ (though $\frac{5+5+5+5+5}{5} \neq \frac{25}{5} : \frac{1}{5}$) and $\frac{25}{\cancel{5}} \times \frac{\cancel{5}}{1} = 25 + 5$ $\left(though\ \frac{25}{5} \times \frac{5}{1} \neq 25 + 5\right)$. Subject focused more on the final result. Subject looked again the goals to be achieved by saying, "it means the answer is 25, and it is added with the number of cans required. This is because the question is about the number of cans before being taken. It means 25 + 5 = 30 cans". Thus the final result obtained by the subject was 30.

At justification phase, Subject prepared the second to solve problems in a math task. Subject attempted to use an algebraic method that had been gained in the previous class, but the subject was less able to distinguish the term algebra and variable. Subject applied the strategy using appropriate notation to formulate a mathematical model as shown in Fig. 3 below.

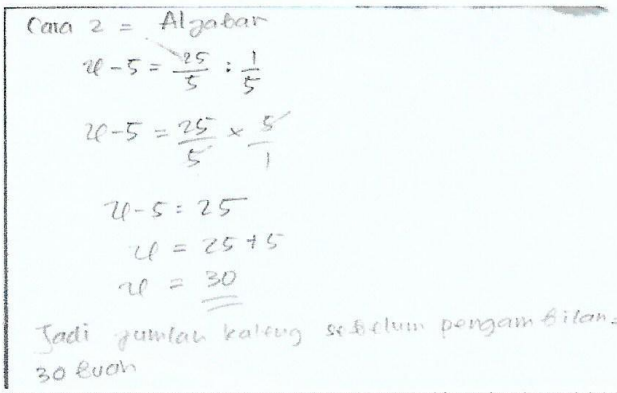
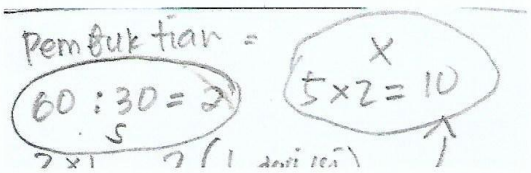


FIGURE 3. THE SECOND WAY OF THE RESEARCH SUBJECT IN SOLVING PROBLEMS ON A MATH ASSIGNMENT

In Fig. 3, Subject implemented the strategy using appropriate notation. Subject let many tin cans before taking x, continued by saying, "because we want to find the number of cans after the decision, then $x - 5$." Subject wrote "$x - 5 = \frac{25}{5} : \frac{1}{5}$", subject was able to use the division operation on fractions by first making 5 as fraction $\frac{25}{5}$ and dividing by fraction $\frac{1}{5}$. Subject made simplified operation of division into multiplication operation on the left side by writing "$x - 5 = \frac{25}{\cancel{5}} x \frac{\cancel{5}}{1}$". The research subject was also able to perform multiplication operations on fraction. In this case subject did *kanselasi* numerator and denominator by the same number that was 5. Then Subject multiplied the numerator and the numerator, and multiplied the denominator and the denominator. Subjects looked doubtful when he wanted to continue the next step. Subject hesitate the completion step that he had written. It meant that the subject was reviewing the step of math task completion, and he finally made a decision by writing, "$x - 5 = 25$". In the next step, Subject summed both sides with the same number (summing up both sides with 5) so that the final result was 30. The subjects made the assertion by making a conclusion "so the number of cans before taking was 30 pieces". For the second completion, the subjects wrote down each step correctly.

Further subject rechecked the correctness of the answers he got as in Fig. 4 below.



Subjects checked the correctness of the answers by linking 30 cans with 60 liters of soy milk. Subjects wrote "$60:30=2$". It meant that 60 liters of soy milk was distributed entirely into 30 cans. Each tin was filled with 2 liters of soy milk. $\frac{2}{5}$ of the can (2 liters) was $\frac{2}{5}$ liter. Subject wrote "$\frac{2x1}{5}=\frac{2}{5}$ ($\frac{1}{5}$ of the can)". After calculating the overall volume of soy milk $\frac{2}{5}$ $liter$ in 25 cans $\left(\frac{2}{5}\times 25=10\ liters\right)$ that contained as much as the volume of the soybean milk in cans $(5\times 2=10)$, the subject concluded that the answer 30 cans was true.

V. CONCLUSION

Reference [10] states that there are three things related to the knowledge of mathematics, namely mathematical operation, mathematical concept and mathematical idea. The mathematical operation is the process of managing and manipulating mathematical information in meaningful ways that support and build on the ideas and concepts of mathematics. Mathematical concept is theoretical, systemic, and generative while the idea of mathematics was derived from one or more of conceptual understanding, the establishment of relation between the conceptual understanding and the formation of new ideas or applications. Students who are able to think *outside the box* are the students who are able to perform mathematical operation correctly to obtain different completion ideas, and different ideas generated use the size of the students themselves. In this research, the research subject used logical reasoning to get a precise mathematical task completion.

Referring to the results of the study, the following is the Description Table of thinking outside the box of students in solving a math assignment using the exploration, ideas generated, and justification.

TABEL 1. THE DESCRIPTION THINKING OUTSIDE OF THE BOX

Exploration phase	• Understand the problem statement by formulating information on mathematical tasks and the objectives to be achieved. • Subjects made markers on the problem statement "(1) Iswanto only needs 5 tin cans to make other cans fully filled; (2) The five empty cans were removed; (3) In fact, the content of each tin at present added exactly $\frac{1}{5}$ from the volume of the can before." • Subjects interpreted the problem statement marked by making a description of the problem situation by writing "5 cans for = all the cans" and "$\frac{1}{5}$ part of can is unfilled".

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