Algebraic creative thinking of undergraduate students of mathematics education program

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Abstract. In mathematics, creative thinking is highly needed to solve a problem; one of them is an algebraic problem. This study was aimed to find out how the ability and character of algebraic creative thinking of mathematics education undergraduate students in group discussion. This study is a case study whereas the method used was a quantitative method. We obtain that some students were not fluent in answering the problem, yet only a few students were flexible in doing that. Many students were also less able to obtain the originality of ideas and elaboration in solving the problems. Also, there were several groups of students who had creative thinking pattern namely Problem-Fluency-Flexibility-Originality-Elaboration. Additionally, this article also described some variations of students' algebraic creative thinking characteristics in each aspect.

1. Introduction
Critical and creative thinking ability become one of the most important and expected factors that human resources can have in the 21st century. The students' competencies in the 21st century are presented in "4C": critical thinking and problem solving, communication, collaboration, and creativity plus innovation which are important to be a foundation for successful learning in schools and careers [1]. In Indonesia, school is expected to be able to emerge character aspects, competence, and literacy on students. The ability of "4C" itself is a competence aspect that consists of critical thinking, collaboration, creativity and communication ability. There are still many teachers who tend to be teacher-centred learning. Meanwhile, there are some weaknesses in teacher-centred learning which likely makes students less active and creative [2]. Therefore, to raise students' creative thinking skills, it requires appropriate strategies that can improve creative thinking abilities, one of which is using student-centred learning by involving group work.

Creative thinking ability is essential in mathematics problem-solving. The ability to think creatively can make students be able to work in mathematics and solve a problem effectively, yet it turns out that not all students can do so. The causes of this phenomenon, related to Sanders, is the difficulties of students to articulate symbols[3]. Thus, some researchers have tried to explain students’ difficulties on symbolic expression in general and other similar symbols [4]. According to Lince, students’ creative thinking ability in mathematics can be reached through many ways, such as discussion, working on problems with many alternatives answers or explanation which contains a varying level of difficulties[5].

Furthermore, group discussion is one of learning strategy to involve students’ collaboration ability. It aims to develop students’ creative thinking ability by sharing knowledge and ideas on a particular
The information which is provided by friends in a group discussion can be used to develop ideas for solving a problem.

Mathematics is a fundamental part of science. According to Acharya, mathematics has been accepted as a critical component of formal education from time to time[6]. Unal argues that a person who has poor basic mathematics will have difficulty in learning Mathematics in his school and social life [7]. Furthermore, Mathematics ability is reflected through mathematics problem-solving ability. Isik&Pilten state that the lack of teachers’ problem-solving ability is a basic obstacle which often appears in learning mathematics[8]. Hu et al. explain that problem solving is closely related to creativity in terms of making logic connections, as well as some problems, are needed to solve through creative thinking[9]. Mathematicians understand that mathematics is a creative subject, but only a few students who unaware about it[10]. In other words, mathematics provides an opportunity for students to think creatively. Indeed, it shows how important giving attention towards students’ mathematics creative thinking ability is, especially on the creative aspect which refers to the activity of producing ideas, approach, or new action [11].

Regarding the previous explanation, creative thinking ability is strongly needed to solve mathematics problems. Tabach and Friedlander state that in order to be creative in mathematics, a student has to be able to think further than the knowledge which has been got[4]. Additionally, Sharma explains that a creative idea is a new, surprising and unusual idea[12]. Utternov and Masalimova argue that a creative person will quickly adapt to the new condition, find a way to overcome difficulties faced, and achieve higher productivity[13]. In brief, a creative person will be able to solve the problems and even look for an alternative method or the best solution.

2. Methods
This study is a case study whereas the method used was a quantitative method. The subjects of this study are 36 undergraduate students of mathematics education study program who take linear elementary algebra subject. The subjects of this study were divided into 12 groups which consisted of 3 students for each. The group member selection was done randomly. Meanwhile, the data collection was done by written test through a questionnaire which was given to each group with a duration of 20 minutes. The given questions were related to finding basis and kernel of a linear transformation from 2 x 2 matrices to a four-dimensional space.

3. Results and Discussion
The data of students’ answers in linear transformation problems from 12 discussion groups have been obtained. Based on the data analysis, the four aspects of students’ algebraic creative thinking ability appear in the answers of their group discussion. Table 1 depicts the data analysis result in answer to each discussion group.

Based on Table 1, on the fluency aspect, there were five groups which provided answers toward the given algebraic questions very smoothly, six groups were in the fluent category, and 1 group was quite fluent. While on the flexibility aspect, there are two groups which were very flexible and were able to provide the answers in three ways, 1 group provided two ways, one of which was wrong in an algorithm, and the rest was quite flexible.

Furthermore, Table 1 also shows that there is only 1 group (K2) which completed the originality aspect by providing solutions which are different from others. While on the elaboration aspect, there are two groups which were able to describe the problems in detail. Since K2 had completed the originality aspect, they were chosen as the subject to obtain more about characteristics of students’ creative thinking.
Table 1. The algebraic creative thinking of students’ group discussion

| No. | Group | Fluency | Flexibility | Originality | Elaboration |
|-----|-------|---------|-------------|-------------|-------------|
| 1   | K1    | 3       | 1           | 1           | 0           |
| 2   | K2    | 4       | 4           | 4           | 4           |
| 3   | K3    | 3       | 1           | 0           | 1           |
| 4   | K4    | 3       | 1           | 0           | 3           |
| 5   | K5    | 4       | 1           | 1           | 1           |
| 6   | K6    | 2       | 1           | 0           | 0           |
| 7   | K7    | 4       | 3           | 0           | 0           |
| 8   | K8    | 4       | 1           | 1           | 0           |
| 9   | K9    | 3       | 1           | 1           | 4           |
| 10  | K10   | 3       | 1           | 1           | 0           |
| 11  | K11   | 3       | 1           | 0           | 0           |
| 12  | K12   | 4       | 4           | 1           | 0           |

Figure 1 shows the response of K2 which is very fluent in providing a solution. However, in fluency aspect, several students were very directed in the process yet do not give an appropriate result as expected. There is also 1 group which shows the effort to gain solution yet the process is undirected. They might not master the basic concept which is related to the question or even not understood what is expected from the given question. As a result, it affects on the inhibition of the thinking process to find a solution.

Figure 1. The result of K2 group discussion on fluency aspect

Figure 2. The result of K2 students group on flexibility aspect
Figure 2 notes that the result of K2 group answers was able to provide more than one solution correctly. They tended to get difficulties in finding other ways to solve the problems. In their efforts, some students tried to give alternatives which unfortunately were not in line with the given question. It was probably caused by the lack of knowledge and the inability to connect related concepts. Consequently, there were only a few students who were able to reach flexibility.

![Figure 3. The result of K2 group on originality aspect](image)

On the one hand, there is only 1 group who gave a different solution to the originality aspect. On the other hand, based on Figure 3, it can be seen that on flexibility toward originality aspect, K2 group has been eligible to be original. However, they did not realise that the alternative solution they have given was different from others.

However, overall, they had not been able to provide any ideas which were unusual and different. Their problem-solving pattern tended to be similar to the pattern that they have already known through the learning activity. Though, their tendency to imitate became an obstacle to the development of their knowledge and mindset, consequently the unique and different problem-solving ideas cannot arise.

![Figure 4. The result of K2 students group on elaboration aspect](image)

Figure 4 depicts the ability of the K2 group to describe the problems well. Only a few groups who were able to do so. It was probably caused by the lack of students’ knowledge about the related concept. Consequently, the refraction of the relation between related concepts might happen. Additionally, the lack of students' understanding of the given problem also became an obstacle.

Regarding the above initial findings, it can be observed that all of the students had similar algebraic creative thinking ability. Generally, the answers result shows the extent of creative thinking ability that can be achieved by students. Another research finding is the character of students’ work in solving mathematics problem which was observed through the result of students’ work, observation, and interviews.

The analysis of character thinking is described as follows. Firstly, the fluency aspect emphasises clear and communicative idea in problem-solving. Some characters, which are found on students’ work, show that there was an attempt of students to understand the purpose of the given question, describe the problem in detail to gain the data, connect the data and the concepts which have been known, and solve the problem systematically.
Secondly, the flexibility aspect highlights generalisation from any ideas so a solution to another problem will arise. On this aspect, students had some characters which showed an attempt to redefine the process of problem-solving which has been done. Another attempt was to develop their knowledge and connect it to other relevant concepts while students also showed the way they developed the framework completion so the new and possible combination can arise. The last attempt was that they tried to rework in groups and were able to obtain a different way to answer.

Thirdly, the originality aspect can be seen in students’ unusual and extraordinary ideas. There are students’ characteristics which indicate an attempt to reexamine the process which has been done. Students also tried to make a combination of out-of-the-box solution and tended to think about how they can find the new thing either from the process or result.

Fourthly, the elaboration aspect can be seen on the development of the problem solving either in general or in detail. Students showed an attempt to evaluate what has been done, develop the previous knowledge, describe and detail the question through the relation between concepts.

4. Conclusion
Creative thinking ability is quite essential for undergraduate students of mathematics education related to algebraic problem-solving. Students need to broaden their thought related to the concepts, the relation between the concepts, and also the algorithm in solving the problem. Meanwhile, the lack of understanding the concept related to the problem causes an obstacle in each aspect of creative thinking as well as the lack of students’ ability in arranging algorithm. Finally, there are several characteristics of algebraic creative thinking of undergraduate students of mathematics education, namely Problem-Fluency, Problem-Fluency-Elaboration, Problem-Fluency-Originality, Problem-Fluency-Originality-Elaboration, Problem-Fluency-Originality-Elaboration, Problem-Fluency-Elaboration, Problem-Fluency-Fluency-Elaboration, Problem-Fluency-Fluency-Originality, and Problem-Fluency-Fluency-Originality-Elaboration.

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