Cultivating Mathematical Creativity Among Students: Learning for 21st Century Education

Nor Haniza Abdul Hamid & Nurzatulshima Kamarudin

***Abstract* – Creativity is a significant part of education development in the 21st century. A creative learning approach is expected to direct creative progression among students, especially in Mathematics lesson. This study was designed with the purpose of examining the effects of Mathematical Creative Approach (MCA) on mathematical creativity in terms of fluency, flexibility, originality, and elaboration components among secondary school students. A pre-test and post-test quasi experimental design was utilised in this study. Mathematical Creative Approach (MCA) was used in the intervention group while conventional learning (CLA) was taught in the comparison group. Samples were selected using a purposive sampling method where there were 32 students in the intervention group and another 32 different students in the comparison group. The research instrument was Mathematical Creativity Test (MCT) and the quantitative data were evaluated using descriptive and inferential statistics. The outcome reveals that the mathematical creativity scores of students in Mathematical Creativity Test (MCT) in both groups was significantly different. On the basis of the findings, the students of the intervention group performed best in all aspects of mathematical creativity; fluency, flexibility, originality, and elaboration of mathematical problems when compared to the comparison group. The research indicates the enormous education benefits of using a mathematical creative approach that aims to stimulate creative activity and innovation in 21st education, particularly in the field of mathematics among students between primary and tertiary level.**

***Keywords* – Creativity, Mathematical creativity, Fluency, Flexibility, Originality, Elaboration**

I. INTRODUCTION

Creative is one of the crucial skills and key to effective education of the 21st century (Kaplan 2019; Richardson & Mishra, 2018; Yuliani et al., 2018; Silvia, 2015). While creativity is considered as an important skill in life, it is also considered essential for a person's cognitive ability to solve issues through the creation of new ideas as it is connected directly to content, knowledge and skill developments (Puspitasari et al., 2019; Beghetto and Karwowski, 2017).

In Malaysia Education Blueprint 2013-2025, the second goal that has been specified is for students to learn how to think in a diversity of cognitive skills, for instance, creative, innovative, problem solving, critical thinking, reasoning, and learning ability (Ministry of Education, 2019; Salleh & Hatta, 2018; Yang & Homg, 2018; Blueprint, 2016).

Nor Haniza Abdul Hamid, Univeristi Putra Malaysia (haniza6385@gmail.com)
Nurzatulshima Kamarudin, Univeristi Putra Malaysia (nzshima@upm.edu.my)

Thus, the development of creativity is a well-discussed topic in the world of education including Malaysia that should be encouraged among students.

One technique that can be used to improve the creativity among students is by applying a learning approach that focuses on four distinctions; fluency, flexibility, originality, and elaboration, which emphasises on the improvement of critical thinking and creative problem solving. Savic et al., (2017) indicated that it is worth encouraging students to think independently and use the mathematical problem to foster understanding and to promote their interest in the syllabus in a creative way. This is true for mathematics education, where educators are supported to use mathematical creativity to improve the curiosity and positive attitude of their students to solve mathematical problems.

II. PROBLEM STATEMENT

Horng et al., (2016) stated that restricting the use of creativity in classrooms diminishes student's natural curiosity and enthusiasm for mathematics, creating a huge problem for mathematics educators who are trying to instill these skills. The use of different approaches to learning also has an effect on the results of student enthusiasm for learning, which cultivates their creativity, curiosity, enthusiasm and excitement. (Ministry of Education, 2019; Nurzatulshima Kamarudin et al., 2017).

The conventional learning approach, focusing on the chalk-and-talk approach and work drilling process has contributed to passive learning atmosphere and poor level of creativity for students in problem solving. (Ministry of Education, 2019; Baharin et al., 2018). Chung and Cheng (2005) observed that this problem needs to be solved by encouraging teachers to employ more systematic, creative and innovative learning strategies to attract students' interest in learning mathematics. This study is thus an effort to study the impact of mathematical creativity approach among secondary school students on their mathematical creativity.

III. LITERATURE REVIEW

Mathematical Creativity

Mathematical creativity is assessed as a main future force and seen as one of the main research priorities (Sawyer, 2019; Regier & Savic, 2019; Akgul & Kahveci, 2016; Greiff et al., 2015; Pitta-Pantazi et al., 2013; Dorn et al., 2012; Riga & Chronopoulou 2012). Sternberg (2006) argues that students can be creative by placing them in a conducive environment. Improving mathematical creativity requires motivation, encouragement, equity and strong support for all students. Educators should develop mathematical creativity in all students so that they may excel in their fields of interest

and can lead the nations in progress (Aizikovitsh-Udi, 2014; Leikin, 2009). Therefore, Mathematical educators have to embrace that mathematical creativity can be enhanced by assisting their students with the right approaches to learning.

While there were various explanations about the principle of mathematical creativity (Runco, 2010; Haylock, 1997; Torrance, 1967), it is defined by four main different categories; fluency; flexibility, originality, and elaboration (Leikin et al., 2013; Lev-Zamir & Leikin, 2011; Taylor, 1975). Fluency is a frequency for relevant ideas and shows the capability to produce various different responses, as explained by Reiter-Palmon et al., (2019) and Torrance (1967). This mathematical creativity component is usually described as the number of relevant responses to a problem. It also linked to the development of thoughts and the procedure of knowledge (Leikin et al., 2013; Faizah, 2011; Leikin, 2009; Haylock, 1997).

Flexibility generally relies on the number of categories in a respondent's ideas or responses, while originality is defined as the uniqueness of the solutions of students. (Reiter-Palmon et al., 2019; Rubenstein et al., 2019; Lev-Zamir & Leikin, 2011). It is perceived as a unique approach to creative products (Leikin, 2009; Torrance, 1967). Meanwhile, according to Leikin & Lev (2013), elaboration is the amount of details given by the respondent and the explanation of the specific problem.

Conceptual Framework

Based on previous literature reviews and the gaps in the literature, the framework of this research was constructed according to research goals. The independent variables of this research are the types of learning approaches. The attributes of the students' mathematical creativity in Mathematical Creativity Test (MCT); fluency, flexibility, originality, and elaboration theory which was described by Torrance (1967) was used as the dependent variable (see Figure 1).

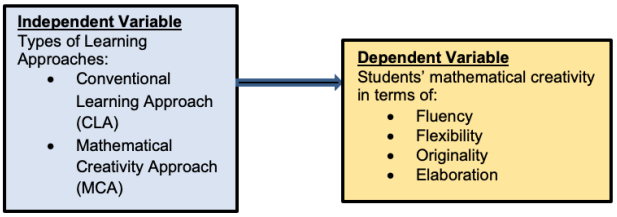

Figure 1. Conceptual Framework

IV. METHODOLOGY

Research Design

The research utilised quasi-experimental quantitative research design, which was constructed using pre-test and post-test. Noraini Idris (2010) stated that experimental design is the most structured experimental study, as the researchers can control the procedures and methods of research design. Meanwhile, an experimental design is an observed study used to estimate the intervention's causal effects (Othman Talib, 2013; Graziano & Raulin, 2010), but participants are not allocated randomly to treatment or control groups in this research. Table 1 shows the non-equivalent pre-test and post-test group of quasi-experimental design.

TABLE 1: THE PRE-TEST AND POST-TEST GROUPS OF THE QUASI-EXPERIMENTAL DESIGN (COHAN, MANION & MORRISON, 2000)

Application	Pre-Application	During Application	Post-Process
Comparison Group	O_1	X_1	O_2
Intervention Group	O_1	X_2	O_2

Remark:

X_1 : Learning using Conventional Learning Approach (CLA)
X_2 : Learning using Mathematical Creative Approach (MCA)
O_1 : Pre-test assessment on students' mathematical creativity in Mathematical Creativity Test (MCT)
O_2 : Post-test assessment on students' mathematical creativity in Mathematical Creativity Test (MCT)

Samples

There were 32 students in the intervention group and another 32 different students in the comparison group. The students in the intervention school were taught using Mathematical Creative Learning Approach (MCLA), while Conventional Learning Approach (CLA) was used for the conventional group of students.

Samples were selected using a purposive method of sampling. The main aim of using the purposive sampling is to emphasize certain features of the chosen group that deliver the best answers to the research aims and the research questions (Graziano & Raulin, 2010; Creswell, 2008).

Referring to Fraenkel et al., (2011), internal validity threats include subject instrumentation, testing, maturation, history, mortality, and implementation. This research examined and managed to control the potential contamination of the results of this study. In terms of their characteristics, every effort was prepared to ensure that the students of the two groups are as homogeneous as possible with the subject of mathematics in relation to age, gender and learning.

Instrument

Mathematical Creativity Test (MCT) which was developed and adapted was used to evaluate the students' mathematical creativity. The following five open-ended problems were selected for this study and illustrated as follows:

- **Problem 1**: Patterns, chains, or sequences of numbers (Mann, 2005; Baker et al., 2001; Haylock, 1997; Kim et al., 1997).
- **Problem 2**: The Sixteen dot problem (Kim & Ahn, 2003; Haylock, 1997).
- **Problem 3**: Problem on polygons (Mann, 2005)

- **Problem 4**: Problem on regular hexagons (Kim et al., 1997)
- **Problem 5**: Problem on classifying of several solid figures (Lee et al., 2003).

This instrument was composed in terms of 4 categories; fluency (a total of accurate answers), flexibility (the number of various categories of responses), originality (the uniqueness of answers), and elaboration (the details and the explanation of the responses), which are the factors of mathematical creativity. A pilot test was directed to different groups of students who were not involved as research samples to assess the reliability of the Mathematical Creativity Test. The α-Cronbach value is 0.843 which is considered as a reliable test.

Methods and materials

Participants in the intervention group were taught using Mathematical Creative Approach (MCA) through courses. Students were also encouraged to think independently and utilize the problem of mathematics in situations of real life to stimulate creativity and increase the skills of their thinking at a higher level (Haylock, 1997). Students were asked to make an effort to share mathematical solutions, compare them and justify ways of reflecting their mathematical ideas. Students were encouraged to develop the course of mathematical lessons by incorporating mathematical creativity into the four dimensions of fluency, flexibility, originality and elaboration (Torrance, 1967).

Students were asked questions such as "How many different techniques would you like to solve that equation..." to stimulate their flexibility element. The student would have to answer with many different ways to expand mathematical solutions for fluency part. In order to enhance the elaboration criteria, students were also asked questions like 'what else...' to expand and resolve their problem solving in mathematics questions. While originality insisted answers like "why…" or "what it is…" to provide the students with unique, unobvious, and new answers.

The students of the comparison group learned mathematical concepts using Conventional Learning Approach (CLA) with the help of recitation and memorization of formulas. The students were also divided into small discussion groups, integrating a work drilling process and, chalk and talk method, and acknowledging learning materials in accordance with the syllabus of mathematics.

V. RESULTS AND FINDINGS

An independent t-test revealed that the intervention group ($M = 58.03,\ SD = 14.54$) has a significantly higher mathematical creativity mean score compared to comparison group ($M = 50.09,\ SD = 16.78$) after the intervention was conducted ($t = 2.02,\ df = 62,\ p < .05$). From the results, it can also be seen that students in the intervention group ($M = 27.41,\ SD = 7.41$) has countered a greater mean fluency score compared to the comparison group of students ($M = 23.84,\ SD = 8.13$). The flexibility score of students in the intervention group ($M = 20.09,\ SD = 4.31$) was also particularly outstanding compared to the comparison group($M = 17.75,\ SD = 4.23$) after the intervention.

Intervention group students ($M = 8.22,\ SD = 4.85$) were the most successful in creating multiple unique answers to mathematical creativity problems compared to comparison group ($M = 6.25,\ SD = 5.64$). The unique solutions answered in Mathematical Creativity Test by students from intervention group which were not found by students in comparison group' solutions are shown in Figure 2. Students in intervention group ($M = 2.31,\ SD = .47$) succeeded in stating higher mean score for elaboration component of mathematical creativity solutions compared to the comparison group ($M = 2.25,\ SD = .57$).

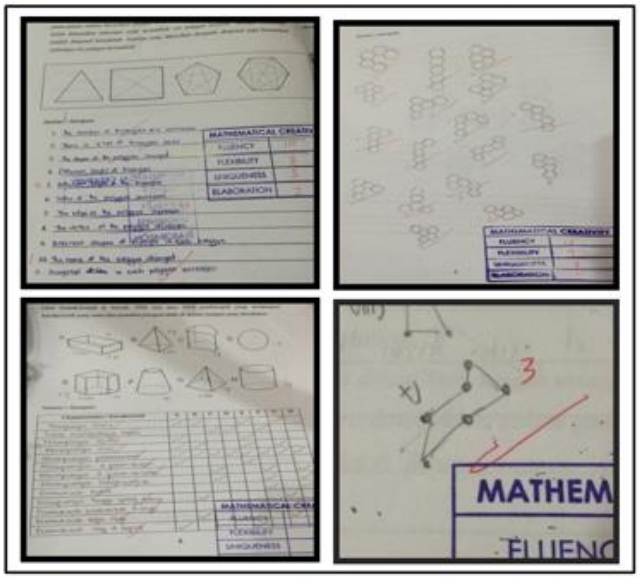

Figure 2. Students' Unique Solutions in Mathematical Creativity Test (MCT)

VI. DISCUSSION

Based on all these findings, it can be seen that the intervention group students which was taught using Mathematical Creative Learning Approach (MCLA), performed better in all different components of mathematical creativity; fluency, flexibility, uniqueness and elaboration for mathematical creativity problems compared to comparison group Conventional Learning Approach (CLA). This implies that the mathematical creative approach has a constructive effect on cultivating mathematical creativity among students.

In addition, students were also shown readiness to take up new tasks, initiate new ideas related to classroom work, mathematical projects and could adapt easily to changes in procedures during the study. In scoring the responses generated by the students in this study, a comparison of the students' mathematical creativity score components; fluency, flexibility, uniqueness and elaboration for both groups in Mathematical Creativity Test are recorded.

VII. CONCLUSION

The outcome of this study shows that the Mathematical Creative Approach (MCA) is much more effective in nurturing the students' mathematical creativity compared to the Conventional Learning Approach (CLA). Moreover, the use of creative approach in schools for mathematical education should be strongly encouraged and used for other subjects in schools as it may stimulate mathematical creativity, divergent thinking, motivation, creative ideas and strengthen students' interest in mathematics. Future research on rich mathematical problems could help improve all students' mathematical creativity.

Nevertheless, a more systematic and long-term study to find out how the mathematical creative approach affects the mathematical creativity of students is really recommended in the future. Educators can relate theoretical processes to practical situations, support modules related to educational studies that are exposed to different creative techniques and incorporate learning strategies that enhance mathematical creativity among students. Utilising creativity as a skill in the 21st century can motivate the students in their education and their futures, careers, and at the same time will participate and inspire them in teaching and learning development.

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