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Following formatting check, the manuscripts are passed on the Editor for a first evaluation. The editor reviews the manuscript and returns the manuscript along with the editorial comments. The editorial process gives the editors the authority to reject any manuscript if it does not meet the scientific publishing standards or is out of scope of the journal. Then, the manuscripts are sent to two or three reviewers. The manuscript is usually sent to two to three expert peer reviewers (double-blind). In this process the peer reviewer's identities are kept confidential and not revealed to the authors. In the same manner the author's identities are not revealed to the peer reviewers. This ensures a fair and unbiased review of every manuscript. This phase lasts approximately two weeks. Each reviewer has one month to complete the review and 15 additional days are given if requested. If the review is not completed within this time, a new reviewer is appointed. The review process lasts approximately two months.

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Research Article

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STEM-MEA (Science Technology Engineering Mathematics - Means End Analysis) Model for Improving the Creativity and Critical Thinking of University Students

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ABSTRACT- This research deals with the implementation of STEM-MEA model (STEM-MEA: Science, Technology, Engineering, and Mathematic - Means Ends Analysis) for the purpose of measuring the creativity and critical thinking of university students. Bt applying experimental research method, and using Liker's scale questionnaires as research instrument, this Research involved 43 students as research samples by assigning them to engage in the following activities: 1) Solving a case by using the concept-map provided by XMIND application, 2) Completing a calculation by using Geogebra application, and 3) Making an interactive product by using Scratch application. The data arising out therefrom were analyzed and resulting in an indication that the application of STEM-MEA model is liable to improve the creativity of the students as proven by their ability to create interactive learning product and to possess highly critical thinking. It was also proven by the acquisition of median value, namely 4, for all questionnaires given to them; which is higher than the average score of liker's scale, i.e. 3. Therefore, it can be concluded that STEM-MEA model is worth using in the learning process for the subjects in physical sciences in higher learning educational institutions.

Keywords: STEM-MEA; Creativity; Critical Thinking

I. INTRODUCTION

Critical and creative thinking skills which have been well developed among the university students all over the world were shaped in such a way by virtue of, among others, the capacity improvement program for the lecturers (Lucas, 2016 ; Harris & de Bruin, 2018; Welter et al, 2017). Any lecturer candidate must first master the critical thinking skill in such a degree that it can thereafter be transmitted to his/her students in order to shape their personality and achievement (Özelçi & Çalışkan, 2019). Jackson (2017) revealed that there are 8 (eight) aptitudes signifying the perspectives of the lecturers to be critical and creative, namely: imaginative, original, curiosity with questioning disposition, sensible, relatable, connecting, synthesizing, capable of expressing thoughtful thinking critically and analytically, and capable of presenting ideas and communicate them with others. All of which shall be the qualities that must eventually be acquired by all university students.

However, the current development in either national or international education shows that there is a tendency of declining in the ability to think critically and creatively among the university students. At national level the critical thinking skill of the students is very low, as found in Malang and Pontianak area (Mahanal et al,2016; Hairida, 2016). Nevertheless, the critical thinking skill of the students in some other countries is also relatively low as found by Adeyemi (2012) in Nigeria, Taleb & Chadwick (2016) in Dubai, and Marin & Halpern (2011) in the United States.

According to PISA (Program for International Student Assessment) Indonesia was ranked 60 out of 65 countries in 2009, 64 out of 65 countries in 2012, 69 out of 75 countries in 2015, and 72 out of 77 countries in 2019 (OECD, 2010; 2014; 2016; 2019) in science scores. Such a low rank indicates that Indonesian students have not yet properly trained for thinking critically and creatively that made them always be in the lowest position (Suprapto, 2016). In addition, most of university students were found to

be less creative when carrying out practical learning activities (Ehtiyar & Baser, 2019). While Carrasco (2017) also found that gender has nothing to do with the lack of creativity and critical thinking skill.

Results of observations to the students in several institutions of higher education revealed that the problems related to the ability of the students to think critically and creatively were prompted by: (1) the carelessness of the students in analyzing the problem; (2) the inability of the students to analyze high-level questions (C4-C6); (3) the passiveness of some students when doing group activity; (4) the difficulty in finding the red-line between concepts and problems for some of the students; (5) the inability of some of the students to express opinions during discussions, (6) the tendency of monotonous learning strategies (7) the lack of problem solving quizzes given to the students applicable for their field of study or their surrounding environments.

In a bid to help the students to be successful in mastering the critical and creative thinking skills, various learning models have been introduced and implemented, such as those by Saripudin (2015) who integrated problem-based learning model with web 2.0 technology, Khairudin et al (2018) who applied Problem Based Learning-based interactive media to improve learning outcomes in Vocational Senior High Schools, Suryani (2018) who utilized web for assessment of standard LAN network competency subjects in Vocational Senior High Schools, Fuad et al (2017) who introduced three types learning models (Remap-NHT Models); and Setiawati & Corebima (2017) who applied PQ4R-TPS Strategy in learning. The critical thinking skill can also be trained through the promotion of argumentative activities and analysis of ideas and questions raised by the lecturers(Cottrell ,2011; Pithers & Soden, 2000). Even though several studies have been conducted for formulating various learning models, but none of which was developed on the basis of STEM-MEA (Science Technology, Engineering, Mathematic-Means End Analysis) which integrates some of the four fields of science, particularly in Data Communication subject. It is in this research, the STEM-MEA Learning Model shall be applied so as to assist the students in practicing their critical and creative thinking skills by using 3 application programs all together in the learning, namely *MindMap*, *Geogebra* and *Scratch*.

II. LITERATURE REVIEW

The Researcher first of all seeks some literatures to support this research so that the research purpose can be achieved. Some of the literature required shall be as follows:

2.1 Learning Theory

Learning is a series of events that allow an interactive engagement between the students and their lecturer, and among the students themselves so as to achieve their goals. Joyce et al (2015) revealed that learning model is a conceptual framework used as guidance in learning process. With regard to the concept of learning model itself, it is described by Trianto (2010) as the guide in planning the learning process either in the classroom or in the form of tutorials. The learning model can be implemented in class for several meetings in one semester. One of approach which can be applied to support the learning process is the STEM approach.

2.2 STEM (Science, Technology, Engineering, and Mathematics) Approach

According to Nessa et al (2017) STEM Model (Science, Technology, Engineering, and Mathematics Model) is a model being created in such a way by blending four scientific disciplines namely Science, Technology, Engineering, and Mathematics. The mixture of the four fields of knowledge is expected to help the students to think critically and creatively. Learning with STEM model has been used through a combination of several learning strategies, such as by Han (2017) who tested the effectiveness of a learning on the basis of science, technology, engineering, and mathematical projects (STEM PJBL) to the achievement of the students in algebra, geometry, probability, and problem solving, and by Sahin et al (2017) who introduced STEM SOS strategy in learning. Application of STEM model and its impact on learning process have also been developed by, among others: Lahti et al (2019); Lebeau et al (2012); Terrazas-marín (2018); Koch et al.(2018); Chiyaka et al (2017); Kan et al (2019) ; Johnson & Keeffe (2016) ; Brändle et al (2018); Kuo et al (2019); Sahin et al. (2017) and Redman (2017). As for in this research, the researcher shall develop STEM-MEA learning model.

2.3 MEA (Means Ends Analysis) Model

In view of its terminology, MEA consists of 3 words namely: *Means* which means many ways, *End* which means the end or goal, and *Analysis* which means systematic analysis or investigation (Sweller & Levine, 1982). The effectiveness of Means Ends Analysis (MEA) Learning Method can be seen from the running of a process for solving problems into two or more sub-objectives. This model is deemed as the development of problem solving method, but the difference is that every problem encountered here shall be broken down into more simple sub-problems and then reconnected into a main goal at the end. Huda (2014) suggested the steps in using MEA, as follows: (1) The teacher presents the problem with a

heuristic-based approach; (2) The students describe the conditions or requirements needed to achieve the final goal; (3) The students divide the problem the teacher has given to sub-problems; (4) The students identify differences based on existing sub-problems; (5) The students analyze the right strategy to solve the problem to achieve the specified goal; (6) The students choose as many strategy as possible for solving the problem and reach the final stage of the problem solving effort. Pratama et al (2017) presented the syntax of MEA model as follows: (1) The teacher/lecturer puts forward the problems relevant to the subject matter of the learning which have connection with local wisdom, (2) The students discuss the problems in each group by adopting the values of local wisdom, (3) The students identify the problems based on group opinions and (4) The students choose the most appropriate strategy to achieve the ultimate goal in accordance with the local wisdom.

This research will combine STEM model with MEA in order to train the students with creative and critical thinking. According to Cottrell (2011) critical thinking is related using the mind. Learning to think in critically analytical and evaluative ways means using mental processes such as attention, categorisation, selection, and judgemen. Brookhart (2010) stated that the students shall have a tendency to possess Higher-Order Thinking Skills (HOTS) which consists of logic and reasoning abilities, analysis, evaluation, creation, problem solving, and decision making (judgment). Higgins (2014) revealed that the ability of individuals to determine the segments of the problem and the ability to show the relationship of those segments or provide arguments that explain a statement signify the form of analytical ability. With the high-order thinking skills already possessed by the students it will help them achieve good learning outcomes. In addition, the learning outcomes are influenced by the evaluation ability of the lecturer in preparing the HOTS-standard questions. The evaluation ability is the activity of making judgments regarding the value of ideas, creations, ways or methods (Tilchin & Raiyn, 2015). With due observance of the opinions of the experts above, the students are required to think critically, analytically and become the problems solvers in facing the examinations being designed in such a way to meet the demands of industrial revolution 4.0 and the needs for skills in the twenty-first century which are relatively complex, in addition to the requirements to have the mental to practice Higher Order Thinking Skills (HOTS).

III. METHODOLOGY

3.1 Type of Research

This is an experimental research which applies STEM-MEA learning model for the purpose of developing the creativity and critical thinking of the university students. The research was performed by involving the students of computer engineering department who take Modeling and Simulation Class with the subject matter called Random Numbers Generation. STEM-MEA model was implemented upon the students by applying the following steps:

I. Giving assignment to the student to solve a case study regarding estimation of the demand for computers within the next 100 days by applying Monte Carlo model for generating random numbers using XMIND application as shown in Figure 1:

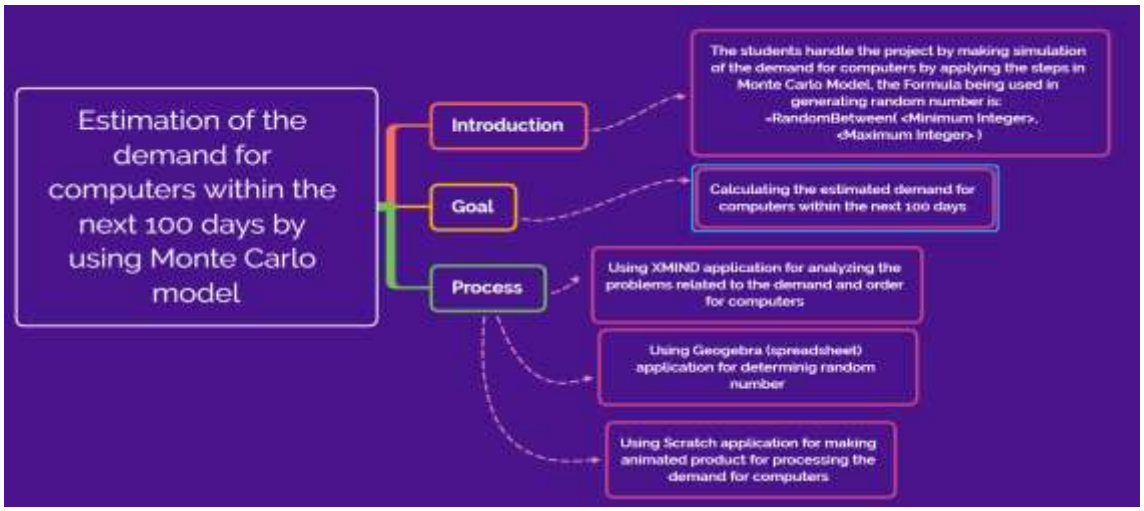

Figure 1. Concept map of the sample of case study with STEM-MEA Learning Model

Figure 1 above shows that the case was resolved by applying three stages, namely Introduction, Goal and Process. At the process stage there are 3 applications being used namely XMIND, Geogebra and Scratch.

II. Using Geogebra application program with spreadsheet for determining the random numbers to be used in the settlement of the case, with the following formula:

=Random Between (<Minimum Integer>, <Maximum Integer>) (1)

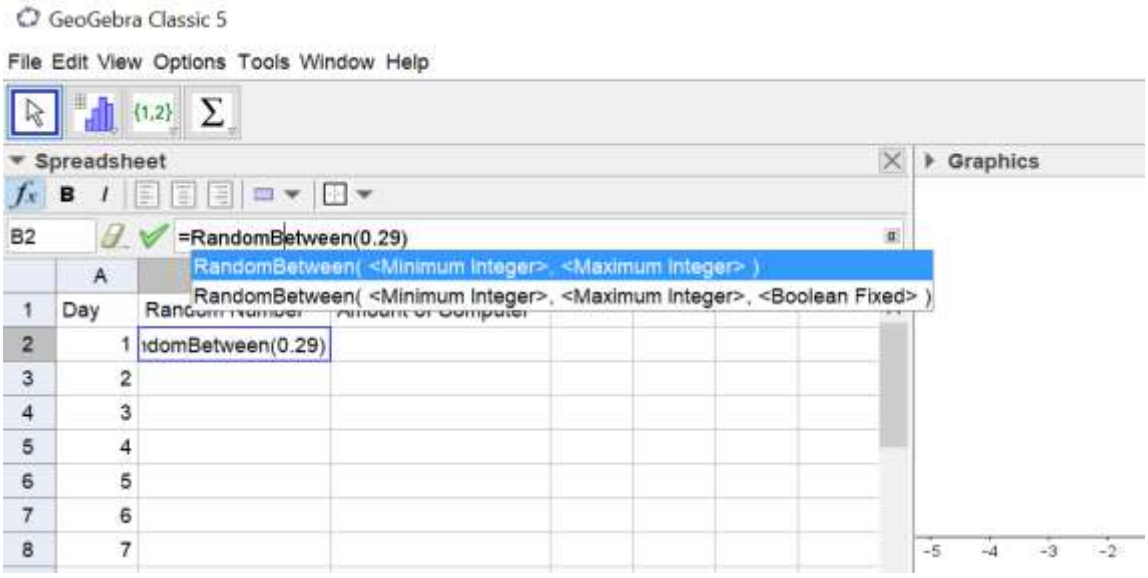

Figure 2. Random numbers generation with Geogebra application

Figure 2 shows that the students have succesfully generated the random numbers so as to quantify the demands for computers within the next 100 days. When one random number has been figured out, then by clicking enter key the next random number can be shown.

III. Using Scratch application for creating an animation regarding the case study on the demand for computers within the next 100 days:

Figure 3. Animation on the simulation of computer demand estimation

Figure 3 shows the simulation process for the emergence of random numbers in the case of Monte Carlo model which thereafter can estimate how many computer orders will come up within the next 100 days. The numbers appear therein shall figure out the number of computer orders per day according to the predetermined interval.

3.2. Samples, Instruments and Variables of the Research

This research involved 43 university students as research samples who were then assigned to fill in the research instruments in the form of questionnaires for finding out their understanding on STEM-

MEA model, and their creativity and learning outcomes. The questionnaire on understanding of the students on STEM-MEA model was made by adopting the form developed by Umar (2017) and the questionnaire on creativity of the students was designed by the researcher herself by measuring the validity and reliability. The variables being measured in this research are as follows:

VP: Variable of student understanding on STEM-MEA learning model being implemented.

VK: Variable of student creativity and critical thinking.

The variable of understanding (VP) was figured out based on questions Q1a-Q1d for giving description on the opinion of the students to STEM-MEA model being implemented. As for the variable of creativity (VK), it was based on questions Q2-Q5, namely regarding 1) Smooth Thinking Skills, 2) Flexible Thinking Skills, 3) Original Thinking Skills, and 4) Detailing Skills (Collaborating).

3.3 Data Analysis Method

Analysis of the data was done by analyzing the validity and reliability of the questionnaires on creativity by using SPSS application program. As for analyzing the variables, it was done by using percentage, median and average values.

IV. Results and Findings

This research implements STEM-MEA model in modeling and simulation learning. To find the results of this research, first of all the the questionnaire on creativity was validated, and then continued by analyzing the questionnaire on understanding of the students to the STEM-MEA model, and to the creativity and critical thinking.

4.1 Analysis on Validity and Reliability of the Questionnaire on Creativity

The questionnaire on creativity consisted of 28 items and tested to all 43 students. The score resulting therefrom was *R Product Moment > r Table*, in which the score of r Table was 0.308 and the percentage of α was 5%. It means that this kind of research instrument has been valid. After that, the reliability of such instrument was measured with the results as shown in Table 1:

Table 1. Results of Reliability Test of the Questionnaires

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.937	**0.938**	**28**

Table 1 shows that the reliability value of the questionnaire was 0.937 which means that the reliability of such instrument was very good and, therefore, such kind of instrument is deemed qualified and worth using.

4.2 Analysis of Students Understanding on STEM-MEA Model

The students understanding on STEM-MEA Model which is the variable on knowledge (VP) in this research was analyzed based on questionnaire items Q1A-Q1D. The score of the questionnaire is shown in table 2 as follows:

Table 2. Students Understanding on STEM-MEA Model

Questionnaire Items	Median
Q1A	4
Q1B	4
Q1C	4
Q1D	4

Table 2 shows that the level of understanding of the students to STEM-MEA model had been satisfactory because the scores reached for each questionnaire items were above 3 on the Liker's scale which was good. Therefore, this STEM-MEA model can be used in Modeling and Simulation course for discussing the subject matters Random Numbers Generation using Monte Carlo Model. Moreover, distribution of the students understanding on STEM-MEA learning model can be seen in Figure 4 below:

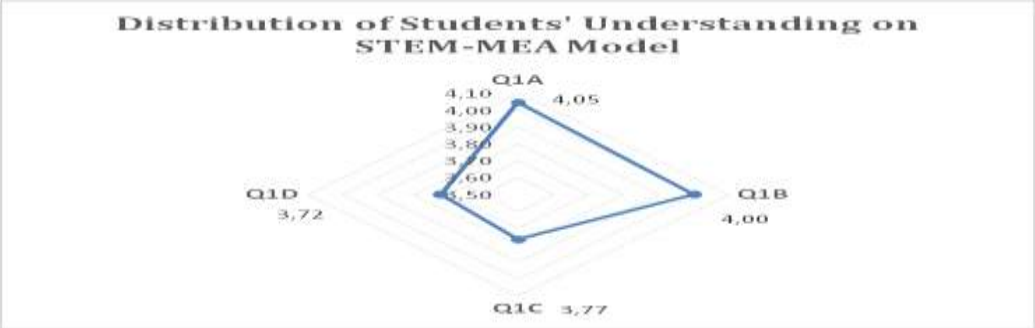

Figure 4. Distribution of Students Understanding on STM-MEA Learning Model

In view of Figure 4 above, distribution of the students understanding on STEM-MEA learning model tends to be positive; it can be seen from the acquisition of the average score which was above 3 on the Liker's scale.

4.3 Analysis of Students Creativity and Critical Thinking

The creativity and critical thinking of the students for the skill variable (VK) were analyzed based on the indicators contained in questionnaire items Q2 - Q5. The score obtained for creativity and critical thinking is shown in table 3:

Table 3. Score for Creativity and Critical Thinking

Questions	Average	Median	Questions	Average	Median
Q2A	3,60	3	**Q3I**	3,21	3
Q2B	3,84	4	**Q3J**	3,47	3
Q2C	3,72	4	**Q3K**	3,74	4
Q2D	3,79	4	**Q3L**	4,26	5
Q2E	3,44	3	**Q4A**	3,63	4
Q2F	3,35	3	**Q4B**	3,84	4
Q3A	4,00	4	**Q4C**	3,35	3
Q3B	3,86	4	**Q4D**	3,44	3
Q3C	3,67	3	**Q5A**	3,95	4
Q3D	3,30	3	**Q5B**	3,95	4
Q3E	3,60	4	**Q5C**	3,53	3
Q3F	3,51	3	**Q5D**	3,51	3
Q3G	3,07	3	**Q5E**	3,65	4
Q3H	3,70	4	**Q5F**	3,79	4

Table 3 shows that the median score obtained from all questionnaire items can be seen from questions Q2 - Q5 with the results of 3 and 4. It means that the creativity and critical thinking of the students tend to be positive during their learning using STEM-MEA model. The creativity indicator for smooth thinking skill was represented by questions Q2A - Q2F, as shown in Figure 5:

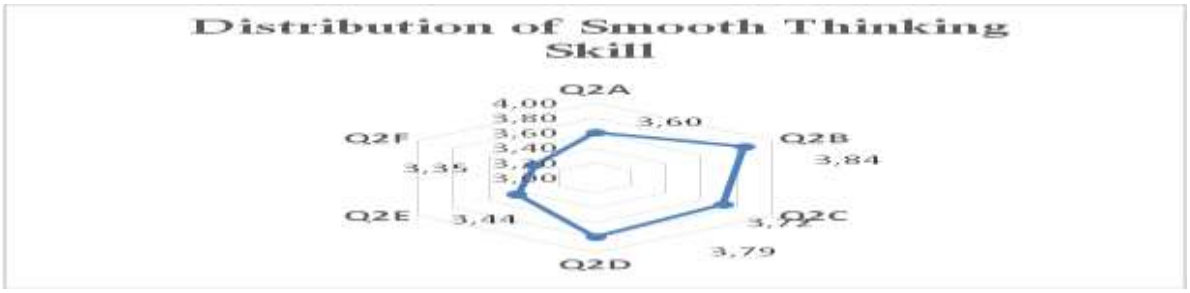

Figure 5. Distribution of creativity indicator for smooth thinking skill

Figure 5 shows that the average acquisition score above 3 indicates that students are able to think smoothly. It is supported by the ability of the students to analyze a problem through the concept map provided by XMIND application program. Furthermore, the indicators for flexible thinking skill were assessed based on questions Q3A-Q3L of the questionnaire as shown in Figure 6:

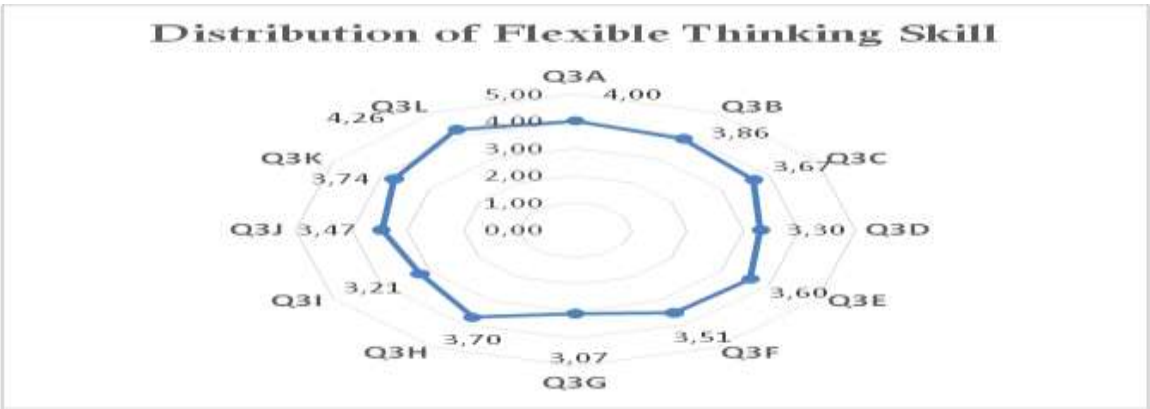

Figure 6. Distribution of Flexible Thinking Skills

Figure 6 shows the distribution of the students flexible thinking skill. The average score obtained from 11 questions being given is above 3, therefore, it can be concluded that students are able to think flexibly. This skill is a very important indicator to show the students creativity, because they can choose alternative solutions for solving the problems as shown in their ability to produce a learning product. Furthermore, this creativity indicator can be seen from the original thinking skills in Figure 7:

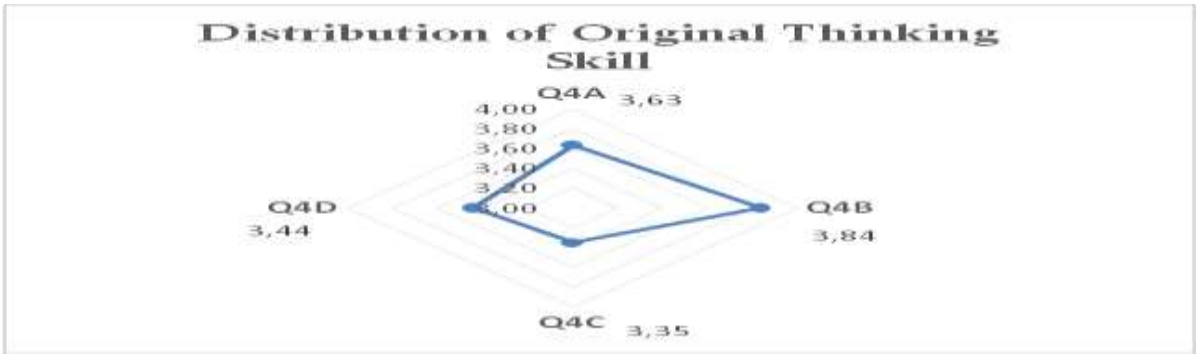

Figure 7. Distribution of Original Thinking Skill

Figure 7 shows the distribution of students original thinking skill being assessed based on questions Q4A-Q4D. The score obtained is similar to those of smooth thinking skills and flexible thinking skills, namely above 3 on the Liker's scale. This score shows that in producing a learning product the students are able to make their very own product based on the results of analysis of the problems they have obtained. The original learning product was produced using the Scratch application which is in line with their lesson material at that time. Furthermore, the last indicator in measuring the creativity of the students is the skill in detailing (collaborating) as shown in Figure 8:

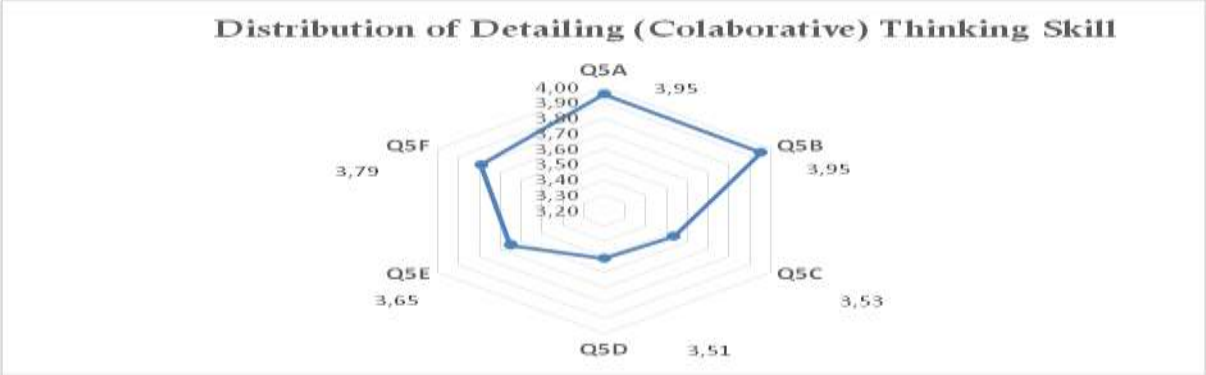

Figure 8. Distribution of Detailing (Colaborative) Thinking Skill

Based on Figure 8, it appears that the student collaboration skills had been good. This can be seen from the acquisition of the average score for all questions which was above 3 on the Liker's scale. The students were able to collaborate several applications in producing a learning product such as combining designing applications to create a sprite in Scratch application. All indicators in determining the student creativity and critical thinking are presented in Figure 9:

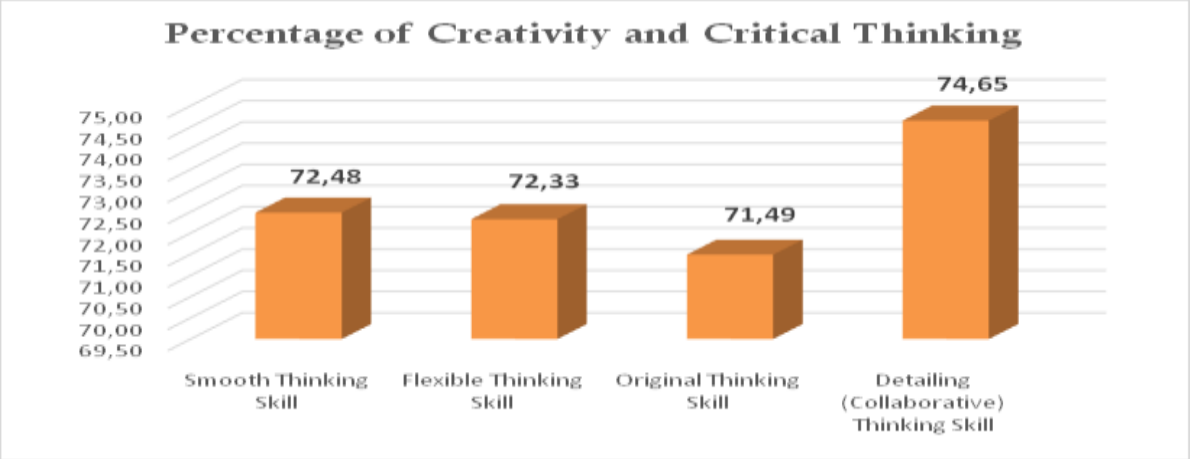

Figure 9. Percentage of Creativity and Critical Thinking

In view of Figure 9, percentage of the students collaborating skill is higher than the other skills. The students are able to collaborate on various application programs and in producing learning products. Some application programs being used can be made by them to be more interesting and easier to use and, therefore, making the learning material easy to understand. All the above means that the students creativity has emerged, and their critical thinking has also been improved as evidenced from the students achievement which tends to increase in their learning activities.

V. Conclusion

Based on the results of the research presented above, it can be concluded that the implementation of the STEM-MEA learning model can foster the creativity and critical thinking of the students. This is proven by the acquisition of median score for all indicators in the questionnaires, namely above 3 on the Liker's scale. The student reception tends to be positive towards the application of STEM-MEA learning model using the application programs like XMID, Geogebra (spreadsheet) and Scratch. Therefore the STEM-MEA learning model is suitable for learning materials requiring analysis and calculation.

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