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Article

Implementing STEM Project to Improve Students' Creativity and Learning Outcomes in the Concept of Circulatory System

Putheary Mom[1*], Sreylin Mom[2], Sokmean Phann[3], Kimsron Srieng[4], Sam Ol Kong[5]

[1,2,3,4,5]Phnom Penh Teacher Education College, Cambodia

**Corresponding Address: mom.putheary@ptec.edu.kh*

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ABSTRACT

STEM education is a learning approach that integrates sciences, technology, engineering and mathematics, and it's an important tool that successfully educates students from a variety of national and cultural backgrounds for improving students' learning activities and learning outcomes. The aims of this research are 1) to investigate the effectiveness of STEM project to improve students' creativity and 2) to examine the effectiveness of STEM project to enhance students' learning outcomes in the concept of circulatory system. The quantitive research was used for this research, and the data was analyzed by using SPSS. The participants of this study were students 8th grade in biology subject in concept of circulatory system. The 36 students were divided randomly into two group. It was found that student groups' product on the average value obtained 77.77% which was categorized as a good creativity level. Moreover, according to the students' post-test result on circulatory system, there was a significant difference between the control group and the experiment group. Thus, the students of STEM project obtained learning outcomes higher than Traditional method. In conclusion, the STEM project has a positive effect to enhance students' creativity and learning outcomes.

INTRODUCTION

In the context of Cambodia, ducation is essential to the economic growth through educational reform (UNICEF, 2018). To achieve the goal of transforming Cambodia into a society based on knowledge, the government needs to improve the standard of education. In order to guarantee that students acquire the necessary knowledge and practical abilities to compete on a global and regional level, quality of education is a critical component. To meet the current needs, MoEYS has implemented numerous approaches and reforms over the years, concentrating on various areas including management, infrastructure, and the quality of teaching and learning (Open Development Cambodia, 2023). However, PISA results shows that across OECD countries, 4.9% of students performed at Level 1b, and only 0.6% of students performed below it. In Cambodia, in contrast, 44% attained Level 1b, and 8% of students performed below it. Students who perform at Level 1b in science can use common content knowledge to recognize aspects of simple scientific phenomena. They can identify simple

patterns in data, recognize basic scientific terms and follow explicit instructions to carry out a scientific procedure (OECD, 2017a).

Consequently, in response to the Royal Government of Cambodia's (RGC 's) vision to turn Cambodia into an upper-middle-income nation by 2030 and a developed nation by 2050, the Ministry of Education, Youth and Sport (MoEYS) has made a significant effort to reform education in order to improve the quality of education, particularly to strengthen STEM education and develop human resources in STEM fields. To align with the RGC's visions and goals, MoEYS has put a strong effort in formulating the New Generation Schools (NGS) and STEM policy in 2016 (MoEYS, 2016). The goal of the NGS and STEM policies is to advance science education, encourage more students to enroll in upper secondary science programs, and encourage them to pursue STEM-related disciplines in college. (Pov, et al., nd).

According to Shero (2020), Traditional teaching methods, which mostly include memorization, lectures, and demonstrations, have been replaced by STEM education and basic skills could not be improved by traditional educational methods. Consequently, STEM education is a different kind of learning that can be implemented to enhance the fundamental abilities required in this century (Sirajudin & Suratno, 2021). When a STEM program is implemented in a classroom or school district, teachers and students participate in interactive, hands-on learning projects more regularly. These activities improve students' knowledge retention and also encouraging the application of critical STEM abilities like creativity and logical reasoning (Shero, 2020).

Circulatory system is one of the most difficult phenomena for students' learning in a biology class (Buckley, 2000). It involves different structures categorized from macro structure such as heart and blood vessels to micro structures such as blood cell and capillaries. Although macro structures can't be seen without visualization tools. Moreover, in order to comprehend circulatory system concepts, students need to know related chemistry and physics concept. Therefore, teachers need to be aware of the difficulties that their students possibly have and implement 21st century teaching approach to support students' creativity and learning outcomes.

Additionally, STEM can be an alternative and approach in learning biology, especially in improving students' creativity (Sirajudin & Suratno, 2021). Creativity refers to the creation of important skill that should be fostered by students (Dawes & Wegerif, 2004). Moreover, in STEM field learning activity is involved in both an individual and a social process (Erol et al., 2015). The goal of STEM activities in the classroom is to raise the standard of both learning outcomes and the learning process. Student-learning outcomes vary in areas, including academic learning achievement, attitude, motivation, and higher-order thinking skills (HOTS). Moreover, some studies said that the learning process and outcomes might differ on many factors, such as the subject of study, learning duration, or even kinds of environmental conditions (Wahono et al., 2020).

Based on Lou et at. (2017) as cited in Hanif et al. (2019) said that various studies have been proved that STEM project gives effects in several aspects and has been measured students' creativity in aspects of adventurousness, curiosity, imagination and challenges. Students' science achievement through implementation of latent growth modelling. Students' creativity through STEM projects has been demonstrated in a prior study (Hanif et al., 2019). The previous study investigated three dimensions of creativity in aspect of resolution, elaboration, and novelty in the concept of light and optics. For further identification, this study will investigate student creativity in the same dimension but in different concept, while the concept that was chosen is circulatory system. In addition, one more previous research focused on effectiveness of STEM on learning outcomes also has been conducted and shown significant results (Wahono et al., 2020). The previous study investigated four criterias such as academic learning achievement, motivation and higher-order thinking skills. However, in this study the estimated learning outcome concentrated only academic learning achievement via test. The

aims of this research are 1) to investigate the effectiveness of STEM project to improve students' creativity in concept of circulatory system model and 2) to examine the effectiveness of STEM project to enhance students' learning outcomes in the concept of circulatory system. Next, about the history of STEM. In beginning the World War II period noticed the development of all STEM-based technologies, which influenced the starting point of STEM's increases. At the time of World War II many innovations were produced with STEM education, but STEM was not applied in education (Juniaty et al., 2016). From 1990 to 2005, the competence of science and math teachers and students remained unchanged. After 2000 many companies have funded research on STEM and have positive impact to education quality (Kuenzi & J, 2008). Following that, STEM education started to be developed and implemented in several of non-Western nations. Back to Cambodia according to CEF Cambodia (2023), several institutions have been established to accelerate the development process of STEM education. The initiation of MoEYS and a prominent NGO called Kampuchea Action to Promote Education (KAPE) in 2014 established the New Generation School (NGS). The goal of this project is to create a "independent" public school with the goal of increasing the standard for Cambodia's educational system to a "maximal" level, especially in STEM fields (KAPE, n.d.)

STEM is acronym of science (S), technology (T), engineering (E) and mathematics (M) which do not exist alone and complex (Pimthong & Williams, 2018). STEM education is a step to break down the four components and to ensure the students improve their problem-solving abilities in everyday life (Ramli et al., 2017). STEM education is a learning that integrates science, technology, engineering and mathematics to develop students' creativity through problem solving (Juniaty et al., 2016). The world has recognized the needs for science, technology, engineering and mathematics to be combined (Rahmi et al., 2017). The teaching and learning of disciplinary knowledge, which includes science and/or mathematics, through the integration of engineering practices and engineering design of appropriate technology is known as STEM integration (Ramli et al., 2017). Based on the experts, the STEM education is a lesson that integrates the four components of STEM which needed in the professional world (Rifandi et al., 2019).

Next discussion about creativity, One 21st-century skill that students need to prepare for their future careers and deal with the advancement of technology is creativity (Hanif et al., 2019). However, the curriculum that has been developed puts a greater an emphasis on the creative aspect of products. Creativity is one of important skills that should be fostered by students (Dawes & Wegerif, 2004). According to Amabile (2012), creativity is the ability to come up with a unique and suitable answer, product, or solution for an open-ended task. When creativity is integrated with technology and education, excellent outcomes can be achieved. According to a recent study, technology enables students to create a variety of media that can support their ability to produce excellent work in a creative context (Loveless, 2002). Because students produce their own ideas to construct the result, STEM projects have the potential to positively enhance students' creativity (Hanif et al., 2019).

According to Hanif et al. (2019), there are three dimensions of creativity in aspect of resolution, elaboration, and novelty. Germinal and Original Criteria was chosen for novelty dimension. Germinal Criteria defined as the product is likely to suggest an additional for the future creative product, while Original Criteria is how the product is unusual and rare to find with the same product idea in a similar experience. Then, Well-crafted and Expressive criteria have been selected for elaboration dimension. Well-crafted Criteria refers to how the product appears and has been worked or reworked with care which idea developed, while Expressive Criteria defined as how should the product is presented with the communicative way and understandable manner. For the last, Useful and Valuable criteria have been selected for the resolution dimension. Valuable Criteria refers to how the product fills the financial, physical,

social, and psychological needs by the judgment, while Useful Criterial refer to how the product has clear and meet the practical application.

Based on explanation above, next discussion about the learning otcomes. According to the University of Toronto (2023), the information or abilities that students should have attained by the end of a specific assignment, class, course, or program have been defined as learning outcomes. Effective learning outcome prioritize applying and assimilation of acquired knowledge rather than simply covering a subject, learning outcomes provide students a clear understanding of how to apply it both inside and outside of the classroom. The effectiveness of learning outcomes in STEM education may be influenced by numerous factors. However, Han et al. (2015) stated that the two most crucial elements were the learning environment and the individual student's level. Consequently, STEM education is an important tool that successfully educates students from a variety of national and cultural backgrounds for improved learning outcomes (Wahono et al., 2020).

STEM education is a teaching and learning approach between two or more STEM components (Tenti, 2021). Education in the fields of science, technology, engineering, and math (STEM) has the potential to enhance the standard of education. According to Lou et al. (2017), there are five stages of STEM project that can be adopted by teachers which consists of preparation, implementation, presentation, evaluation, and correction (Lou et al., 2017). Helping students comprehend the issue, its scope, and its theme is the goal of the preparation stage. During the implementation stage, students had to create a project based on their design drawings and carry out the test. Students must present the project result at the presentation stage. The teachers required to provide an assessment or recommendation regarding the students' project during the evaluation stage. Students were encouraged to make corrections in accordance with the evaluation during the correction stage.

METHODS

The study used quantitative approach design to investigate the STEM project on students' creativity and learning outcome in the concept of circulatory system.

Sample and population in this study was conducted in one of a lower secondary school in Phnom Penh, Cambodia. The participants of this study were students in 8^{th} grade in biology subject in concept of circulatory system. There were 36 sample size which classified into control and experimental group. In experiment group was applied STEM project that divided into 4 groups and control group students was applied Tradition Method (TM) and learned through a text book. Students in each groups were taken by a simple random sampling for this study, which allows to selection of participants for the study randomly (Noor et al., 2022).

The research instruments included creativity rubric assessment and achievement test were used to collect the data needed in this study. Research instrument that used as creativity product analysis matrix (CPAM) that was developed by Besemer and Treffinger (1981) which was used by Hanif et al. (2019), and academic learning achievement test focused on Circulatory System which divided into three parts involved multiple part which has five questions, labeling the circulatory system with seven labels, and analytical part has two questions.

The stages used in this study consist of preparation, implementation, presentation, evaluation, and correction (Lou et al., 2017). This study needed fourth meeting time period to finish all stages of STEM project. The activities of each stages as in the following (1) first meeting, researcher conducted preparation stage which led students to understand the concept of STEM, find out the information on the internet, discussed on materials, and outline their design product. (2) Second meeting, researcher conducted implementation stage which students create Circulatory System model product based on their outlined design. In this stage, students spent two weeks on their project and facilitated by researcher. (3) Third meeting, researcher conducted presentation and evaluation stage that provided opportunities in each

group to present and comments on their project to enhance product. And (4) fourth meeting, researcher conducted correction stage which provided second opportunity in each group to presentation about their product again after students received recommendation. Moreover, in this stage researcher assessed product in each group by using CPAM.

Data collection in this study has been conducted for a month. There were two types of tools in this research, the data collection divided into two parts. 1) In order to assess students' creativity, the researcher used CPAM in three dimensions such as resolution, elaboration, and novelty. 2) Before starting the STEM project, students both group in STEM and TM group were assigned to do a pre-test about circulatory system. After finishing the project, students were reassigned to do post-test on the same topic.

The data on students' creativity and learning outcomes were analyzed by using SPSS program (Statistical Product and Service Solution). The descriptive statistic and the inferential statistic were used to analyze the data. The descriptive statistic was used to analyze the frequency, mean and standard deviation. While, the independent t-test was used to compare mean score of pre-test and post-test in both groups.

RESULTS AND DISCUSSION

Results Students' Creativity

The result shown on the student groups' creativity of circulatory system model. The students' creativity production was assessed by using creative rubric assessment. It was assessed through three dimensions of creativity rubric assessment including novelty, resolution and elaboration. In each dimension consist two criterial and 3 score was used to measure the level of creative in each criteria. The 3 scorings are 1 score: low level, 2 score: medium level and 3score: high level. Novelty dimension consist two criterial include germinal and original. Valuable and useful was criterial of resolution dimension. Elaboration dimension consist two criterial such as well-crafted and expressive.

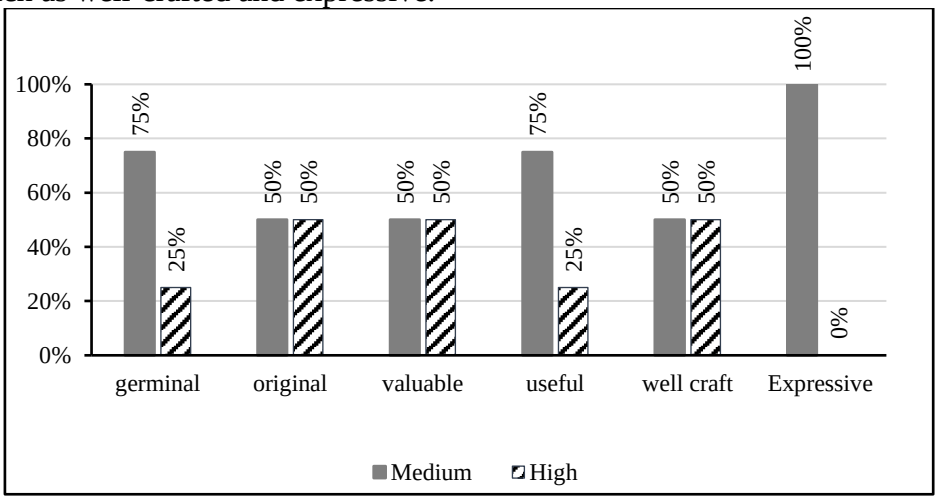

Figure 1. Frequency Level in Each Creative Criteria

According to the result in figure 1 shows the percentage of level in each creative criterial of three dimensions. All group of students' products were in the medium and high levels of each creative criterial. As the result in figure 1 medium level was higher percentages than high level. The first dimension was novelty: medium level of germinal was 75%, high level 25%, and original was 50% equal in medium and high level. The second dimension was resolution: Medium level and high level of valuable and usefulness was the same percentage 50%. The third dimension was Elaboration: Well-crafted was 50% equal in medium and high level, and Expressive only obtained in medium level was 100%.

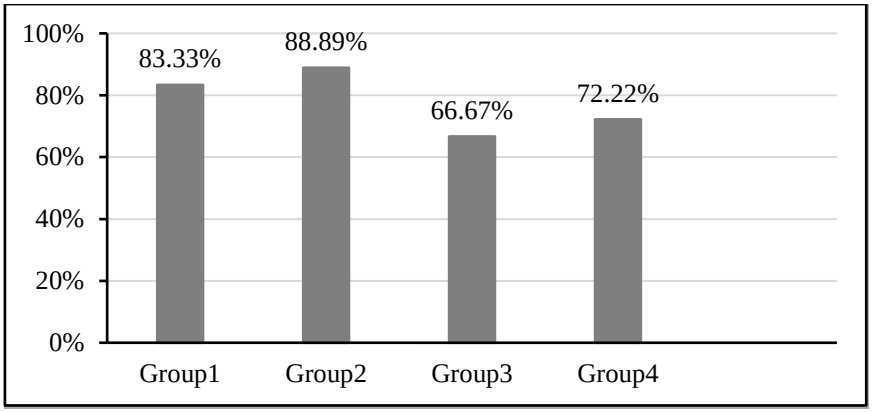

Figure2. Creativity Groups on Producing Circulatory System Model
(0-20 Very less, 21-40 Deficient, 41-60 Adequate, 61-84 Good, 85-100 Very good)

Based on the results in Figure 2, student groups' products achieved different levels of creativity. Group 1 obtained 83.33%, Group 2 obtained 88.89%, group 3 obtained 66.67% and group 4 obtained 72.22%. The highest percentage was group 2 which achieved very good creativity, while the lowest percentage was group 3 in the level of creativity. The groups with good creativity level were group 1, group 3 and group 4. Thus, the creativity groups on producing circulatory system model shown positive results which can enhance students' learning.

Table 1. Average Percentage of Creativity

Group	N	Minimum	Maximum	Mean	Std. Deviation
Group creativity	4	66.67	88.89	77.77	10.14
Valid N (listwise)	4				

The table illustrates average percentage of creativity groups. The minimum percentage of 66.67% was a good creativity level and maximum percentage of 88.89% was a very good creativity level. The mean percentage of four groups obtained 77.77% with SD=±10.14. Therefore, the students' creativity was good level based on mean value.

Students' Learning Outcomes

Table2. Compared Students' Pre-test Achievement Score between Control and Experiment Group

Group		N	Mean	Std. Deviation	Std. Error Mean	*p*-Value
Pre-test	control	18	16.67	6.962	1.641	0.532
	experiment	18	15.33	5.646	1.331	

The table 2 indicates the mean score, standard deviation and *p*-Value of Control group and Experiment group. This result shown that the pre- test mean score of both groups were below average. While, the independent t-test is p=0.532>0.05. It revealed that the students' basic knowledge of the circulatory system was not different in both groups.

Table 3. Compared Students' Post-test Achievement Score between Control (TM) and Experiment Group (STEM)

	Group	N	Mean	Std. Deviation	Std. Error Mean	*p*-Value
Post-test	Control	18	19.94	7.84	1.85	0.000
	Experiment	18	31.44	6.68	1.57	

According to the result in table3, the mean score of post-tests of experiment group was higher than control group. The control group was applied Traditional Teaching method obtained (M=19.94, SD=7.84) and the experiment was applied STEM project obtained (M=31.44, SD=6.68). It indicated that the mean score of control group was below average and experiment group was above average. The independent t-test illustrated the *p*-value,

p=0.000<0.05. This result confirmed that there was a significant difference between students' post-test achievement score of experiment group and control group.

Discussion

Based on the results, this research showed the effectiveness of STEM project implementation to improve students' creativity in case of producing the circulatory system model. Based on the three dimensions of creativity, it was found that the medium level was higher than the high level in each dimension. In the Novelty dimension include two criteria such as Germinal referred to the product inspires others to design a creative product. The students' circulatory system model gained 75% of medium and 25% of high level germinal. It revealed that their products could use to enhance others to have more creativity for the future products. Original: Students' products achieved 50% of high level as well as medium level. It meant that students used the previous knowledge or others model as the ideas for designing products, and they add some own ideas to make their own creative products. In the Resolution dimension included valuable and usefulness found that there was 50% of medium level valuable which the model compatible with objective but incorrect some concept of circulatory system such as labeling component of circulatory system, arrow direction of blood flow and coloring blood vessel, and usefulness students' products were useable and understandable.

Therefore, their Circulatory System model could use as a learning material to explain the circulatory system concept. In the elaboration dimension consisted two criteria such as well-crafted: Students' products were good-looking, interesting, and understandable. Moreover, the products were created by spending less budget and using simple material that could be found in daily life. In addition, the expressive indicated the students' presentation and understanding level by using products. In this case, the products were presented by lacking body language, make some eyes contact, missing some information about the products and infrequent interaction with the audiences. However, after the implementation of STEM project in classroom, even though the products were not developed with a completely novel concept, it could strengthen students understanding of science in the circulatory System and improved their designing and using of technology.

In addition, according to the data analyzed of creativity group shown that there was a group which had very good creativity products and three groups' products were categorized as good creativity. Based on the average value obtained 77.77% which was categorized as good creativity. As a result, the products of the groups achieved a good creativity level and the circulatory system model was designed in different ways by each group. Thus, STEM project implementation improved students' creativity. Moreover, the result of this study related the previous research. Hanif et al. (2019) found that the STEM project implementation had a positive impact on students' learning because students produced their own ideas to construct the results, STEM projects have the potential keys to positively enhance students' creativity. This finding was similar with the previous study which was found that the student's creativity improved through implementation STEM project based learning (Setiawan et al., 2020).

It can be seen that STEM was so important approach for learning in science subject because can stimulate creativity thinking of students. From this approach, student can interest which one component of STEM that can be increased their creativity. Maybe there was student that interest with science first, or technology based. This explanation was so appropiate with the student era that was digitalization. So there was STEM education can help the teacher to train the creativity thinking of students well.

The second aim was to investigate the effectiveness of STEM project to enhancing students' learning outcomes. According to the students' post-test result on circulatory system lesson, there was a significant difference between the control group and the experiment group. It illustrated that the STEM project implementation shown significant impact which was shown

the increasing in students' learning outcomes which was higher than Traditional method. The previous study showed that the circulatory system is one of the most difficult phenomena for students in a biology class (Buckley, 2000). In this case, The STEM project plays as an active instructional approach in classroom that allow students applied their knowledge of circulatory system to create a model of circulatory system. Therefore, the students gained a better understanding of this concept than the traditional methods which were students learning as passive learners. According to the previous study by Tomlinson (2002), the classroom that applied traditional instruction, students are the passive learner who are passively receive the information, taking note and listening what teacher says. Based on this finding, it could be concluded that the STEM project implementation improved students learning outcomes. This finding was in line with the previous study by Azhar et al. (2022) which students learning outcomes in science were increased by applied STEM based learning, so it had a positive effect on students learning outcomes. The similar study was found that STEM knowledge has a positive influenced on creative product, ability to solve issues related with STEM and student's creativity (Mayasari et al., 2016).

CONCLUSION

According to the findings, the result of this research is similar to the previous studies. Through the implementation of the STEM project in classroom, the students achieve a good creativity categorize on their product in case of producing a Circulatory System model. Moreover, students who learnt through implementing STEM project they gain a better understanding of lesson concept than those who learnt through traditional method. The statistic revealed that there is a significant difference between STEM project and traditional method in term of students learning outcomes. As the result shown, this study can be concluded that the STEM project has a great effect on enhancing student creativity and improving students' learning outcomes.

This research was conducted with students only in the 8th grade and with a small sample size. Furthermore, the students experienced in STEM education learning approach was for the first time, and the assessment of the students' creativity was applied only in the biology lesson. Therefore, the future researcher should choose students from different levels and sample sizes. In order to make the assessment of students' creativity more accurate, the researcher should assess the students' product varieties of times with different concepts.

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