The Effect of STEM Autonomous Learning City Map Application on Students' Critical Thinking Skills

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Abstract—This research aims to discover the effect of STEM autonomous learning city map application on the students' critical thinking skills. The design of the research is quasi-experimental with pre-test and post-test control groups. The population of the research is the fourth graders of an elementary school with a total of 60 students involved as the research samples. To collect the data, the research instruments used are a test and an interview. The test is to gain the data of the students' critical thinking skills while the interview is to gain information regarding the students' experiences with STEM autonomous learning city map. The findings revealed that there is a significant difference of the critical thinking skills between the students of both groups (Asymp. Sig. 2-tailed = 0.015, $p<0.05$). The critical thinking skills of the students in the experiment class were increased by 23.7%. In addition, compared to the students in the control group, those in the experimental group showed a more positive attitude towards their experiences of learning using STEM autonomous city map application. Owing to this, it can be concluded that learning with the STEM autonomous learning city map application can affect students' critical thinking skills positively.

Keywords—autonomous learning, city map application, critical thinking, elementary school students, STEM

1 Introduction

As the 21st century unfolds, the world enters a new era called the Information Age, which is marked by rapid adoption of new technologies. To adapt to life in the 21st century, it is necessary to possess 21st Century skills. Skills that are essential to society's prosperity in the 21st century are known as 21st Century Skills. They are not academic skills but rather the skills that will be needed in order to succeed in today's world [1]. In short, if students want to have a successful career in the future, it is imperative that they develop these skills in the classroom.

Science plays an increasingly important role in the 21st century. The pace of scientific discoveries and technological advancements is extremely swift [2]. One possible

way to keep up with it is through STEM education [1]. STEM stands for Science, Technology, Engineering and Mathematics. It is a learning approach suitable to help improve students' skills in the 21st century [3]; [4]. The STEM education contextualized teaching in real-world problems, which in return causes the discipline practices to be more relevant to students and teachers [5]. Through STEM learning, students are trained to face authentic problems that aim to challenge them with various situations in their daily lives [1]; [6]; [7]; [8]. Thus, introducing STEM to students at all levels of education is highly required and necessary [8].

Having STEM competencies is crucial for current and future education because every country in the world recognizes the need to develop a skilled workforce and knowledge generation that will drive economic growth [9]; [10] and technological innovation [11]. High value and knowledge intensive activities are increasing in today's world of work, and as a consequence, there is a growing demand for people with high level and economically valuable skills. Owing to this, STEM becomes central and has an important role in developing and contributing to the scientific innovations that drive the next generation of data-driven economy [12].

STEM education can help students have a balance between hard skills, soft skills, and creativity [13]. STEM learning urges students to be capable of solving problems with high creativity and collaboration [14]. In brief, STEM learning is currently needed in the world of 21st century education to allow students to think critically and creatively. Students' ability to think critically and creatively is a valuable skill that is essential for dealing with numerous challenges in their social and personal lives [15]; [16]; [17]; [18]; [19]. Students' ability to think critically required them to dig and show higher thinking order by understanding problems, planning solutions, and executing solving plans. STEM learning oriented towards problem solving will edify students to always think analytically and scientifically, which ultimately results in the improvement of their critical thinking skills [20].

One effort to enhance students' critical thinking skills in learning is by employing learning media that allow students to study independently, locate and solve existing problems, and be active participants in the learning process [21]; [22]. Teachers and students can use a media-based application or website to support students' critical thinking skills. A medium integrated with a global positioning system (GPS), such as Math City Map [23], offers authentic learning for students. As supported by Takeuchi et al. [24], successful STEM teaching relies heavily on the learning environment. Thus, the researchers decided to apply STEM learning with GPS integration that is called STEM Autonomous Learning City Map. This application is a brand new learning medium that has a purpose of supporting students' critical thinking skills. By integrating this application in the classroom, it promotes the improvement of students' motivation and critical thinking skills since the students are able to practice through hands-on and direct experience.

2 Literature review

2.1 STEM learning

STEM education has gained much attention internationally. It is a sort of learning integration which is integral to the progressive curriculum in the 21st Century [25]. The main objective of STEM learning is educating and familiarizing students to think scientifically [26]. In addition, STEM learning can influence students' motivation in studying an object and enable them to carry out the creative process and get experience directly from what they are studying [27].

The background of STEM is to educate students to have competitive expertise globally, particularly in the 21st century skills [28]. For students, STEM learning is regarded as a bridge between education and career [29]. This means that students with good STEM competencies have a guarantee of a successful career in the future. Lack of STEM implementation in the education field can affect the economic and political strength of a country [30]; [31]. In the implementation of STEM learning, teachers need to identify characteristics of students, the learning approach that will be used, and the delivery of the said approach [32]. The application of STEM learning is expected to shape and make students able to complete tasks and solve problems with critical thinking, creativity, good communication, and teamwork [14].

In summary, STEM education is carried out to train and equip students with scientific and technological knowledge, strategies, and life skills that are needed in order to compete in the 21st century [33]; [34].

2.2 STEM autonomous learning city map application

Outdoor learning can support development of knowledge and understanding of students about the environment through direct involvement [35]; [36]. Using mobile technology by integrating with GPS or Google Maps may increase students' motivation to study as they complete exercises while also experiencing them. Because of this, the researchers developed a STEM autonomous learning city map application that can help teachers give variation in learning which is different from their regular practice. Teachers can invite students to learn new things while actively exploring the environment around since this application is integrated with GPS.

STEM ALC Map is an application that can be used in STEM learning that directs students to complete tasks by exploring environment around following coordinate points contained in the map in the application. To complete their mission, students must follow steps and coordinate points on the map based on the order that has been set and answer the questions given to them. After answering the questions, students will know the total score they get. The questions presented in the STEM autonomous learning app can be in the form of essay, short answer, and multiple-choice.

2.3 Critical thinking

Critical thinking is one of the mandatory skills required for students to have in the 21st century. Critical thinking is needed to face challenges and problems in daily life [37]; [38]. Facione [39] stated that critical thinking skill is a self-control ability to decide something that involves interpretation, analysis, evaluation, and inference as well as information delivery using evidence, concept, methodology, criteria, and contextual consideration. Similarly, Choy and Cheah [40] claimed that critical thinking is a complex process that requires a high cognitive level in processing information. Ennis [41] also suggested that critical thinking is the ability to think reflectively and reasonably focusing on what is believed or done. Critical thinking ability covers clarifying, making decisions, making conclusions, giving further explanation, giving estimation and integration, and other abilities [15]; [42]; [43].

Critical thinking ability is a competency that students must have. Critical thinking has proven to prepare students in various disciplines because it involves cognitive activity where students have to focus on making decisions about what to believe or do [44]. To simply put, Abdullah [45] asserted that critical thinking is a process that aims to make students able to make decisions and consider what is best for their learning. Critical thinking ability of every individual may vary depending on the regular practice that is facilitated by teachers to develop students' critical thinking [46]; [47].

According to Anderson [48], when critical thinking is developed, someone will tend to look for truths, have divergent thinking (open and tolerant to new ideas), analyze problems well, think systematically, have full curiosity, behave in a mature and responsible way, and think independently. Students who think critically will have good reasoning skills, take decisions bravely, and be consistent with their decisions [49]; [50]; [51].

3 Research methodology

3.1 Participants

This research used a quasi-experimental method with pre-test and post-test control group design. The purpose of the research is to increase critical thinking ability of elementary school students through active learning using the STEM Autonomous Learning City Map application. This research was implemented at a public elementary school in Pekanbaru, Indonesia. It was conducted in the even semester of 2021/2022 with the total samples of 60 students at the fourth grade, which were divided randomly into two groups; 30 students for control class and 30 students for experiment class.

3.2 Procedures

This research was started with observation of facilities and infrastructure of the target school and followed by development of the instrument to take research data. Instruments used in this study are a critical thinking ability test and an interview. In addition, the researchers also developed worksheets on the concept of comparison to determine

parts of plants, which then were inserted into the STEM Autonomous Learning City Map app. Class activities using this application were held in five meetings. At the first meeting, the students were introduced to the application, including how to use the application, creating students' accounts, and answering pre-test questions. Then at the next meetings, the students worked in small groups using the STEM Autonomous Learning City Map app. After that, the students were given a post-test at the end of the learning.

3.3 Instrument

The instrument used to collect the data is a critical thinking test which consists of five question items. The results from the test were categorized using a 4 point Likert scale. Other than the critical thinking ability test, the data was also taken from observation and interview after the learning process took place [49]. Data collection process in this research lasted for a month.

3.4 Data analysis

This research was carried out face-to-face with stages in accordance with STEM learning syntax contained in the lesson plan. Hypotheses in this research are as follows:

Ho: There is no difference in critical thinking skills between students taught with conventional learning and students taught with the STEM Autonomous Learning City Map application.

Ha: There is a significant difference in critical thinking skills between students taught with conventional learning and students taught with the STEM Autonomous Learning City Map application.

Data analysis was performed using a non-parametric correlation test, namely Chi-Square Test [50]. The researchers selected this type of test because the data were not normally distributed. Then the data was analyzed using the SPSS computer program.

4 Results and discussion

4.1 The learning process using STEM autonomous learning city map

Learning activities in both experimental and control classes focused on measurement, comparison, and analysis of body parts of plants. Learning process was organized in five meetings for each class. Specifically in the experimental class, at the first meeting, the researchers introduced and explained how to use STEM Autonomous Learning City Map app for the classroom teacher and the students. In front of the class, the researchers explained the procedure to use the STEM Autonomous Learning City Map app that had been downloaded by the students. The steps of using the application are as follows:

1. Log into STEM Autonomous Learning City Map application. Choose the "log-in class" menu, type the class code in the box and then click "enter".

2. To return to the home screen, click "menu" and "refresh". Then the class will appear.
3. There are two different sub materials in the class: (1) calculate the height and length of the flag's pole; and (2) determine parts of plants. You can pick which lesson you want to do first.
4. After choosing one material, read the instructions first. After that, click "start trials".
5. When '*ask permission access location'* notification appears, click "allow".
6. Every point has 1 question. To find the point where the question is given, click the point then click Google maps.
7. After arriving at the target point, click "do". Read the question carefully, answer it correctly then click "save".
8. Go to the next points until all questions have been answered. Then, click "submit".

After the explanation on how to use the application, the students were given a pre-test to evaluate their ability before learning. The pre-test was done by students individually within a certain time. At the next meetings, the research team facilitated students' learning using the STEM Autonomous Learning City Map application in small groups. The students were also provided with worksheets that they had to complete together while going around using the app. This activity allowed students to cooperate and collaborate to work on every question. Some documentation of the students' activities can be seen in the following Figure 1, Figure 2, and Figure 3:

Fig. 1. Students measuring the length of flag pole's shadow

Fig. 2. Students measuring their friend's height

Fig. 3. Students looking for types of plants

At the end of learning, the students took a post-test consisting of 5 questions. This post-test was done individually to measure the levels of critical thinking ability of the students after the learning process with STEM Autonomous Learning City Map application took place.

4.2 The test results of students' critical thinking skills

The students' critical thinking skills were measured through a critical thinking test given at the beginning and end of learning. The Chi-Square test results that have been conducted using SPSS 20 are presented in Table 1 as follows:

Table 1. Chi-square test results

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	52.950	33	0,015
Likelihood Ratio	58.411	33	0,004
Linear-by-Linear Association	8.914	1	0,003
N of Valid Cases	120		

As shown in Table 1, the value of Asymp. Sig (2-tailed) is 0.015, which is less than (<) 0.05. Thus, the H_0 is rejected, and it can inferred that there is a significant difference in critical thinking skills between students taught with regular learning and students taught with the STEM Autonomous Learning City Map application ($\mu_1 \neq \mu_2$). From the average score achievement, it can be seen that the experimental class have better scores after treatment than the control class.

Using the autonomous STEM application in the learning process made participants become more active and enthusiastic. This application is included in the *mobile learning* app, a software program that can be used well on computers and mobile phones to fulfill certain learning needs. *Mobile learning* app is one trending app in the field of educational technology which is expected to be able to facilitate learning of all levels and becomes a solution to problems in education [54]; [55]. This technology as a learning medium can help enhance students' motivation and their concentration [56]; [57]; [58].

Science in this learning process can be seen when the students identified parts of the plants. Students knew patterns of leaves, shapes of leaves, shapes of roots, shape of stems, and the benefits of those parts. *Technology* was involved when the students utilized mobile applications and internet networks to reach their learning goals. *Engineering* in this study was seen in the students' measurement methods, which included (1) measuring with 1 ruler which was used repeatedly by leaving marks at the ruler's end and summed up for total measurements, and (2) measuring with multiple rulers to find out the height of their friend and the length of flagpole's shadow. Meanwhile, *mathematics* presented in this learning was the students counting the comparisons of the measurement results between flagpole's shadow and their friends' height.

In addition, from the results of the interview, the students claimed that the learning process using the STEM Autonomous Learning City Map application was more fun than the usual conventional learning carried out by teachers in the classroom. This can be seen on the survey results where 90% of students chose 'very good', indicating that this app had made the learning to become more interesting and easier.

By using the app, the students affirmed that the learning becomes more meaningful since the students can explore and apply their knowledge directly in the field, causing

them to be able to comprehend the concepts that were being discussed. The following is some of the statements given by the students in the interview:

S1 (F): *Learning with this application was fun, we could recognize plants, and we could measure the height of friends directly using a ruler.*

S2 (KNA): *The learning is enjoyable. We walked around the school looking for various kinds of plants; there were mango trees, hibiscus flowers, roses, and more. In addition, we also liked to measure the length of the shadow of the flagpole together.*

S3 (HA): *Learning with the application was more enjoyable because we could learn outside the classroom and it made us not feel bored. If we study in class, we [usually] feel bored and sleepy.*

In general, the use of the STEM Autonomous Learning City Map app has benefits in learning, which is helping students practice solving problems independently and encourage them to collaborate and have discussions. As a result, this affects their critical thinking ability positively to solve problems that they might face in any situation. As supported by Berland and Steingut [14], learning with STEM applications can shape and assist students to be capable of solving problems critically, creatively, and communicatively. This can be seen in the process of STEM aspects carried out by the students as explained previously.

Furthermore, based on the results of the pre-test and post-test, the critical thinking ability of the students in experiment class experienced significant improvement by 23.7% compared to those in control class, which only increased by 23.4%.

5 Conclusion and recommendation

Having conducted the research concerning improving students' critical thinking skills using the STEM Autonomous Learning City Map application at SDN 192 in Pekanbaru, it can be concluded that learning using the STEM Autonomous Learning City Map app can increase students' critical thinking ability. The result of the Chi-Square test showed the value of Asymp Sig. (2-tailed) is 0.015, which is less than (<) 0.05. Therefore, it can be determined that the H_0 is rejected. That means there is a significant difference in critical thinking skills between the students taught with conventional learning methods and the students taught with the STEM Autonomous Learning City Map application.

Owing to this, the researchers would like to recommend this application for teachers to use as an instructional medium both at formal and non-formal educational settings. This STEM Autonomous Learning City Map app encourages students to be more active in the learning process and develops their knowledge on their own. In addition to math and science lessons, this application can actually be applied in other subjects. Using this application helps teachers to liven up a new atmosphere in the teaching and learning process. For future researchers, the researchers suggest that they develop various kinds of questions with more varied routes using this app so that students can explore more knowledge.

6 Limitation

The limitations faced in this study were the limited availability of smartphones since elementary school students are not allowed to bring smartphones to school. Not only that, the internet connection has to be stable, for it is a GPS-based application which requires high speed internet access. If the internet network is slow, it will cause the application to load very long, which results in the user being unable to continue their learning process using it.

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