Developing STEM autonomous learning city map application to improve critical thinking skills of primary school teacher education students

The problem and the aim of the study. Critical thinking is one of the skills that is needed in the current Industry 4.0 era. In PISA 2019, Indonesia is ranked 71st with an average score of 396 points in science performance, which is still classified as low. Therefore, a solution is needed in order to enhance the critical thinking skills of Indonesian students. Integrating technology in the classroom is important in today's learning. Using technology-based learning media makes it possible for teachers to upgrade and improve the learner-centeredness of their lessons. One of these technology-based media is an application. Seeing how common and usual it is for students to use digital devices and internet in everyday life, the researchers then decided to develop an android-based application called “STEM Autonomous Learning City Map” which aims to facilitate students to learn actively and independently in order to improve their critical thinking skills. With this application, students are expected to face problems they are encountered and find solutions on their own.

Research methods. This research was carried out at the PSTE study program, FKIP, Universitas Riau in the even semester of 2021/2022. Using Research and Development (R&D) design, this research applied the ADDIE model which consists of five stages (Analysis, Design, Development, Implementation, Evaluation). At the Development stage, a validation test was conducted with a media expert to determine whether the product that has been developed is appropriate for use or not. Then at the Implementation stage, a field trial was carried out with the subject of 60 PSTE students at Universitas Riau. Owing to this, the type of data obtained in this research is both qualitative and quantitative.

Results. The result of the validation test by media expert gained an average score of 79.19, which can be categorized as valid. Then data analysis at the Implementation stage using the Paired Sample T-Test via SPSS found an Asymp (Sig. 2-tailed) value of 0.006, which is less than 0.05. This implies that there is an improvement of mean score in the post-test done by the students. For this reason, it can be concluded that the STEM Autonomous Learning City Map application is valid and feasible to be used as a learning medium, and has a positive influence on students’ critical thinking skills.

Conclusion. The STEM Autonomous Learning City Map application that has been developed is valid and appropriate to be used as a medium in the learning process. In addition, based on the results of the paired sample t-test, this application is also proven able to improve students’ critical thinking skills. This can be seen from the increase in the average score of students after learning using this application.

Keywords: research and development, application, STEM Autonomous Learning City Map

For Reference:
Introduction

The development of science and technology in the current era of globalization continues to experience very significant progress. This progress has affected almost all aspects of life, including education [1; 2]. Information and communication technology that develops in the field of education was marked by the existence of ICT-based learning media [3]. This can be seen from the Government's program for schools to apply technology in learning activities in the classroom. Through the use of technology in the classroom, learning becomes positive and interesting [4; 5]. However, not all of the technological products can be used relevantly for education, especially for learning processes and outcomes. Technological products, such as biotechnology, microtechnology, and materials, are actually not directly used as tools and materials for learning. Thus, the relevant use of technology is depended on the meaning and purpose of the learning itself. Aspi et al. [4] mentioned that learning is essentially a transactional communication that is reciprocal between teachers and students, students and students, and students and the learning environment in an effort to achieve learning objectives. There is a core principle of learning; it must contain elements of communication and information. Therefore, the technology directly related to learning is information and communication technology [6]. The use of ICT in learning generates fundamental changes in the way teachers teach and students learn [7; 8]. Therefore, integrating ICT in life, particularly in the field of education, is an important thing to do at this time.

There are at least four important components in building a learning culture using the ICT model in schools. First, students are required to study independently with various appropriate approaches so that they are able to direct, motivate, and regulate themselves in carrying out their learning activities. Second, teachers are asked to develop knowledge and skills, facilitate learning activities, understand the nature of learning and the things needed in learning. Third, there should be availability of adequate infrastructure to facilitate learning activities. Fourth, the administrators should be creative and supportive of it [9].

Teachers must be able to use technology due to the importance of ICT in education. The ability of teachers to integrate ICT into the learning process will also have a significant impact on students' ability to achieve learning objectives [10; 12]. As a result, teachers must be able to design creative and innovative learning that is integrated with the use of ICT [13]. Creative and innovative learning created by teachers will undoubtedly affect students' lives. It will help students succeed in learning, create solutions in solving problems, give a feeling of pleasure and satisfaction in the learning process, and so on. With the existence of technology in the world of education, learning activities become more varied, which causes the learning atmosphere to be less monotonous and far from boring [14].

Learning using technology prepares students to be able to take meaning from information and develop it into new knowledge. They are also trained to evaluate the knowledge that long exists in order not to be left behind by scientific advances. For this reason, the provision of learning materials and educational technology which includes educational facilities, textbooks, and science books, is used as well as possible to increase students' understanding of what they are learning [15]. Andri [16] publicized the important role of technology in improving the quality of education. The role of technology can increase the
effectiveness and efficiency of the teaching and learning process, which makes it easier for educational goals to be achieved.

Critical thinking is a process of testing, connecting and evaluating every aspect of a problem. These skills are included in higher order thinking involving cognitive processes in analyzing problems systematically and specifically. Critical thinking, which often also refers to problem-solving, requires students to use and apply their knowledge to a real life scenario. Students with critical thinking skills will manage to thoroughly distinguish and identify problems they encounter, and find solutions to solve them [17]. Suryaningsih and Dewi [18] stated that critical thinking is rational and reflective thinking that focuses on what is believed to be true. 'Rational' means beliefs and arguments based on actual, relevant and reliable evidence. As a result, critical thinking skills need to be developed from an early age so that students are able to face challenges in the future [19; 20]. When critical thinking skills are developed, a person will tend to seek the truth, think divergently (open and tolerant of new ideas), be able to analyze problems well, think systematically and independently, be full of curiosity and be mature in thinking [21]. Critical thinking includes disposition and ability. These are the two things that describe a person. From a developmental psychology perspective, disposition and ability reinforce each other, so they must explicitly work together. Disposition (character) is, for example, brave, cowardly, never give up, easily give up, and so on. John Dewey describes the character aspect of thinking as a "personal attribute". A human character (disposition) is an internal motivation that is consistent within him to act and respond to a person or event. Various experiences strengthen the theory of human character (disposition) which is marked as a tendency that can easily be described, evaluated, and compared to other people. Knowing a person's disposition allows us to predict how that person might react in various situations. In contrast to character, ability is manifested in the form of deeds. Someone with good abilities tends to be able to make fewer mistakes in doing tasks, compared to those with bad ones [22].

Indonesia is ranked 71st in PISA (Program for International Student Assessment) 2019 with an average score of 396 points on the aspect of science performance ability, which is still categorized as low [9]. Critical thinking skills with science performance abilities have a fairly strong relationship with a percentage of 41.5%. In short, it can be stated that Indonesian students still have low critical thinking skills. Therefore, a solution is needed in order to enhance the critical thinking skills of Indonesian students.

One of the technologies that is often used in learning is application-based media. Android is a mobile device based on Linux that includes an operating system, middleware, and applications. Android is an open platform on which developers can build their own applications. Mobile applications are applications that run on cell phones and can be used as media to process, obtain, and share information. They are not time bound and can be carried anywhere [23]. This then makes applications practical to be used because as long the users have digital devices, such as smartphones, tablets, laptops etc., they can operate them anywhere and at any time. To put it simply, application is a program that is ready for use anytime and made to carry out various functions for its targeted users [24].

Considering the importance of building critical thinking skills for students and integrating technology-based media in the learning process, the researchers then decided to develop an application called "STEM Autonomous Learning City Map". This application is developed with the purpose of creating an innovative learning medium that can provide facilitation for students to learn actively and independently. Active learning essentially means student-centered learning and is used to optimize the potential of students [25]. STEM education,
the other hand, is known to shape creative and critical thinking mindset in young people by making them face and solve the problems they encounter. As a result, this STEM Autonomous Learning City Map is expected to increase students' critical thinking skills because it urges them to be active and critical problem solvers.

The STEM Autonomous Learning application is based on a location map (GPS). The GPS (Global Positioning System) is a system that can be used to determine the location of coordinates on the earth's surface [26]. Thus, this application directs students to the location of problems, so that they can solve them and learn something directly from them [27].

Regarding learning for children, STEM and Loose Part method is one of the best alternative learning methods to restore the nature of children's learning [28]. As matter of fact, this method is in conformity with the curriculum of Indonesia, the 2013 curriculum, in which the learning in preschools employs a scientific approach consisting of observing, asking, exploring, associating, and communicating [29], which is basically the foundation of STEM. This process of teaching and learning activities is not only carried out in the classroom but also outside of it as long as the environment is determined as safe and nurturing for children's development.

Methodology

This research was conducted at the PSTE (Primary School Teacher Education) study program at Universitas Riau in the even semester of 2021/2022. Using the Research and Development (R&D) design, this research employed the ADDIE model consisting of five stages.

The first stage is Analysis. This stage is related to the analysis of work situations and the environment so that the right product can be determined to be developed. The second stage is Design where two designs for the research were done, namely the design of research instruments and the design of research products that was about to be developed according to needs based on the data from analysis stage. For the design of the research instrument, it contains an assessment instrument for the product that would be carried out by an expert.

The third stage is Development. At this stage, the product manufacturing and testing is carried out based on the design that has been made in the previous stage. The result of this stage is an application-based learning media called STEM Autonomous Learning City Map. After the product has been developed, it needs to be validated by experts to find out whether it is valid and appropriate for use or not. In this case, the expert is only a media expert because the product is an application. There are five aspects of assessment for the validation; correctness of content, language, operation, design, format, and functionality. If the product is declared valid by the expert, then the research can continue to the implementation stage where the product will undergo a field test. However, if the product is declared invalid, it needs to revised first following the suggestions by the expert until all the improvements are complete, and it becomes a valid product that can be used for the next stage.

The fourth stage is Implementation. At this stage, a field test is carried out where the product that has been made is implemented in the environment in which it is to be used. In this study, the STEM Autonomous Learning Map was tested on test subjects, namely the PSTE students at Universitas Riau, totaling 60 students. The researchers provided as many as 20 questions in the application that contain problems that need to be solved by the
students. The results obtained were then analyzed using SPSS 20 with a quasi-experimental normality test, homogeneity test, and paired sample t-test to see whether there is an effect of using this application to improve students' critical thinking skills or not.

The fifth as well as the last stage is Evaluation. This stage is carried out to assess whether each step of the activities to develop the product is in accordance with the specifications or not. In addition, the practicality of the product being developed was also evaluated. Not only evaluation but suggestions regarding the development of this product for the future were also given at this stage.

Owing to all this, the type of data obtained in this research is both qualitative and quantitative. The quantitative is for the data of the validation test and the SPSS tests while the qualitative data is for the suggestions and input which became a reference for the researchers to revise the STEM Autonomous Learning City Map application that was developed.

**Results**

This development research yields a product in the form of learning media, the STEM Autonomous Learning City Map application, which was ready to be validated and implemented in order to test its functionality and attractiveness in learning. The findings of this study can be seen from the results of the media feasibility test and the improvement of students’ critical thinking skills. The presentation of the results of this research is presented according to the development stage of the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation) as follows:

**Analyze stage**

Before product development is carried out, the first thing to do is to analyze the needs of users, namely teachers and students. This analysis is carried out to ensure that the product developed is according to the needs of the targets. The first analysis is the ability of teachers and students to use technology, such as Android and Windows. Overall, teachers and students have been able to operate Android, but students have not been able to operate Windows properly and correctly. The second analysis is the availability of learning tools to maximize the learning process with the help of the product to be developed. It was found that there are still many schools with inadequate learning equipment facilities, such as only having 1 projector and not having a Chromebook. Because this product is an application that runs on Windows and Android, the analysis of internet network availability is also carried out. It was found that not all schools have a network or Wi-Fi. Schools that have a Wi-Fi also experience problems, such as slow network that is not connecting to devices.

**Design stage**

1. Assign a development team
   In this study, the development team consisted of primary/main developer, expert validator, practical validator, technicians, and users.

2. Create development schedule
   Media planning is carried out for about 1 month. Media development was done for almost 10 months. After the media has been worked on, it was validated by an expert
and practical validator which took almost 1 month. As a whole, the development of STEM Autonomous Learning City Map media took approximately 1 year.

3. Make a history board

The storyline is designed so that application development was structured and well organized. After analyzing the capabilities and needs, the products to be used for learning activities were designed before being developed. The design of a STEM application began with the creation of a use case diagram that describes the interaction between systems as shown in Figure 1.

![Use case diagram](image)

**Figure 1** Use case diagram

After completing the use case diagram, the researchers proceeded with making a Data Flow Diagram (DFD) which describes the flow of a process or system as shown in Figure 2.

![DFD of STEM application in Indonesia](image)

**Figure 2** DFD of STEM application in Indonesia
The next step is preparing tables used to store information about objects that was represented in a database or known as a Relational Database. The following figure is a display of the STEM Autonomous Learning City Map application.

4. Determine product specifications
The product developed is an application-based learning media that requires an internet network that can be accessed by students and teachers via personal computers (Windows) or smartphones (Android).

**Development stage**

Learning media in general displays; (1) opening page; (2) login page; (3) dashboard which contains the main menu; (4) profile page used to set user name and password; (5) the class page used to create classes; (6) task pages used to make questions about the topic learned; (7) route page used to show the locations of questions/problems that must be solved by users; and (8) value recap page. Figure 3 below shows the display of STEM Autonomous Learning City Map application:

![STEM autonomous learning city map application](image.png)

**Figure 3 STEM autonomous learning city map application**
This developed learning medium can be run on Windows and Android platforms. After the product has been developed, the next thing to do is to test and assess whether the product is valid and appropriate for use or not. Because the product is an application, the validator is only a media expert. The assessment consists of content correctness, language, operation, design appearance, format, and functionality. The result of the assessment is presented in Table 1 and Figure 4.

<table>
<thead>
<tr>
<th>Assessment Aspect</th>
<th>Percentage (%)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Correctness</td>
<td>80.13</td>
<td>Valid</td>
</tr>
<tr>
<td>Language</td>
<td>79.15</td>
<td>Valid</td>
</tr>
<tr>
<td>Operation</td>
<td>77.23</td>
<td>Valid</td>
</tr>
<tr>
<td>Design</td>
<td>75</td>
<td>Valid</td>
</tr>
<tr>
<td>Format</td>
<td>81.35</td>
<td>Valid</td>
</tr>
<tr>
<td>Functionality</td>
<td>82.25</td>
<td>Very Valid</td>
</tr>
<tr>
<td><strong>Total Mean</strong></td>
<td><strong>79.19</strong></td>
<td><strong>Valid</strong></td>
</tr>
</tbody>
</table>

The result of the validation test conducted by the media expert on the content correctness aspect, linguistic aspect, ease of operation aspect, design aspect, format aspect, and functionality aspect obtained an average score of 79.19%, which is categorized as valid. Therefore, this application is appropriate for use and can undergo a field test at the implementation stage where the product is implemented in the learning process.

**Implementation stage**

The subjects of implementation for the application is 60 PSTE students at Universitas Riau. The learning process carried out using the STEM Autonomous Learning City Map application has the goal, which is to establish active and creative learning for the students. The students are expected to think critically to solve problems they encountered through
the questions presented and construct concepts and knowledge independently. Critical thinking skills of the students are tested when they go looking for answers presented in the questions. The change in students' critical thinking skills before and after using the STEM Autonomous Learning City Map application can be seen from the results of the pretest and posttest.

The data collected during the implementation stage is divided into pre-test and post-test data. SPSS 20 was used to analyze this information. The amount of data, maximum value, minimum value, average value, and standard deviation are the results of descriptive statistical analysis performed on both pre- and post-research data. Table 2 shows the results of descriptive analysis performed with SPSS in this study.

![Table 2](#)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Test</td>
<td>60</td>
<td>56</td>
<td>98</td>
<td>82.95</td>
<td>9.175</td>
</tr>
<tr>
<td>Post-Test</td>
<td>60</td>
<td>65</td>
<td>98</td>
<td>87.10</td>
<td>6.932</td>
</tr>
<tr>
<td>Valid N</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the table above, it can be seen that there are 60 samples of both the pre-test and post-test. The pre-test has a minimum value of 56, a maximum value of 98 with an average score of 82.95 and a standard deviation of 9.175. Meanwhile, the post-test has a minimum value of 65, a maximum value of 98 with an average score of 87.10 and the standard deviation of 6.932. For this reason, it can be ascertained that there is an increase in the average score from before using the application to after using the STEM Autonomous Learning City Map application.

1. Prerequisite Tests
   Normality Test
   The normality test was done to determine whether the samples of the research are normally distributed or not. The data used are the data from the pre-test and post-test of students in the experimental class at the implementation stage. The researchers did a normality test using the Kolmogorov-Smirnov test. The output of the normality test is as follows:

![Table 3](#)

<table>
<thead>
<tr>
<th>Class</th>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Test</td>
<td>.111</td>
<td>60</td>
<td>.061</td>
<td>Normal</td>
</tr>
<tr>
<td>Post-Test</td>
<td>.102</td>
<td>60</td>
<td>.196</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Table 3 shows that significance values of the pre-test and post-test data, which are 0.061 and 0.196. Both are greater than (>), 0.05. Therefore, it can be confirmed that the data distribution of the research samples is normal.
**Homogeneity Test**

The purpose of homogeneity test is to find out whether a variant of the data from two groups is homogeneous (same) or heterogeneous (not the same). Thus, a homogeneity test in this study was carried out to find out whether the research data variance was homogeneous or not. The SPSS output of the homogeneity test is as follows:

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.805</td>
<td>1</td>
<td>118</td>
<td>.053</td>
</tr>
</tbody>
</table>

As exhibited from the table above, the significant value of the data is 0.053, which is greater than (> 0.05. Therefore, it can be ascertained that the variances of the research data are the same or homogeneous.

**Hypothesis Testing**

After confirming that the research data is normally distributed and homogeneous, the researchers tested the hypothesis using a paired sample t-test through SPSS 25. This test is to compare the mean of the pre-test data and the post-test data to see whether there is a significance difference in students' critical thinking skills between before and after using the application. The output of the paired sample t-test is shown in Table 5 below:

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std. Deviation</th>
<th>95% Confidence Interval of the Difference</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.150</td>
<td>1.485</td>
<td>Lower -7.090 Upper -1.210</td>
<td>.006</td>
</tr>
</tbody>
</table>

As presented in the table above, the p-value for the sample t-test is 0.006, which is less than (<) the standard significance level, 0.05. This demonstrates that there is a significant difference between the mean score of the pre-test and that of the post-test. Owing to this, the H0 is rejected and the Ha is accepted. With an average score difference between the two data groups being -4.150, it can be concluded that there is a statistical increase in students' critical thinking skills after learning using the STEM Autonomous Learning City Map application.

**Evaluation stage**

The final stage of the ADDIE model development research is evaluation. At this stage, the evaluation of the results and drawing conclusion is carried out. Based on the results obtained from the validity test and the implementation of the media, it can be concluded that the STEM Autonomous Learning City Map application is suitable and useful as a learning medium. This medium is found to be able to help students become more active and creative as well as to improve their critical thinking skills. This can be seen from the mean increase obtained before and after using the STEM Autonomous Learning City Map application (Table 2) in the learning process.
The results of this study indicate that the implementation of the STEM Autonomous Learning City Map that was developed increased the average score of students from the pre-test (82.95) to the post-test (87.10). This means that there is a significant increase in critical thinking after using this media. This was also proven by the hypothesis testing using a paired t-test ($p$ value 0.006 < 0.05). These findings are in line with Yavuz et al. [72] who also found that STEM application can improve the 21st century skills which contains five aspects; informational and technology literacy skills, critical thinking and problem solving skills, entrepreneurship and innovation skills, social responsibility and leadership skills and career awareness. So, building students' critical thinking skills is very important to do. The importance of 21st century skills, especially critical thinking, is very relevant to the needs of today's times [45; 46]. As stated by NAE and NRC, STEM education aims for preparing the next generation to learn and employ the 21st century skills [44]. For this reason, critical thinking becomes the foundation of a successful education in this globalization era [47]. How these skills are developed and improved depends on how the teacher facilitates the learning [30; 31].

Creating learning settings that support critical thinking in students and putting into practice instructional strategies that support critical thinking [46; 48]. The most widely used definition of critical thinking is provided by Facione who describes it as a purposeful, self-regulatory judgment that produces interpretation, analysis, evaluation, and inference, as well as an explanation of the evidential, conceptual, methodological, criteriological, or contextual consideration upon which that judgment is based [49; 50]. Critical thinking, Ennis [51] stated that reasonable reflective thinking that is focused on deciding what to believe or do, while Russell mentioned that critical thinking includes attitude, knowledge, and thinking skills [52; 53].

The ability to think critically is very important in preparing students, particularly PSTE students, to face the revolutionary era 4.0. this is because learning based on 21st century skills does not only prioritize cognitive abilities, but also process skills [32]. Critical thinking abilities support educational objectives and are essential in today's globalized world since people are no longer expected to know their place (metaphorically speaking), but rather to choose their own position [50; 55]. The ability to think critically is not enough to be used as an educational goal, but also has to be a basic process that allows students to overcome future problems in their environment [33]. In fact, critical thinking abilities are emphasized and thought to be one of the most crucial abilities for success in life [50; 56]. In order to encourage and deliver critical thinking more comprehensive and humanistic, phenomenological pedagogy gives students the chance to reflect on the significance of lived experiences of individuals, families, and communities as they develop through discourse [57; 58].

This increase in critical thinking skills also occurs because students felt more interested in learning using this application. Incorporating STEM applications into the learning process is expected to boost students' enthusiasm and motivate them to participate more actively. In addition, Students must actively participate in the processes of conceptualizing, applying, analyzing, synthesizing, evaluating, and presenting information in order to practice critical thinking [59; 60]. Active learning is very necessary because each student has a different way of learning. There are those who like to learn by reading, discussing, and there are also those who like to practice directly [34]. The promotion of critical thinking abilities through active learning has been advocated [58; 61]. Numerous active-learning activities help students...
become stronger reasoners and thinkers [62]. An active-learning strategy transitions students from passive to active participants [63]. The active-learning technique that was employed (small groups, scenarios, case studies, etc.) did, in fact, enhance students' critical thinking abilities [64; 65]. Often referred to student-centered instruction, it is usually understood as when students 'do’ the learning and think about what they are doing [53; 66]. In addition, it is an educational strategy in which students are engaged in higher-order thinking (analysis, synthesis, evaluation). Hence, the phrase essentially captures what is happening in a student's mind, regardless of whether the body (or mouth) is physically active [67]. At the same time, critical thinking is a higher order thinking ability. Higher-level thinking abilities go beyond discovering and memorizing simple information. Those are the characters that are expected to be developed by students; critical, inventive, and creative [47; 68].

This application is also a set of software that can be utilized effectively and flexibly through computers or other digital devices to meet specific learning requirements and provide solutions to today’s educational problems [37; 38]. The integration of digital technology is thought to enhance learning process quality and foster the development of higher order thinking abilities, which are associated with 21st century capabilities [69]. Students must therefore receive critical thinking instruction in the classroom [70; 71]. When used as a learning medium, the STEM Autonomous Learning City Map application can help hearten students and enhance their focus to study [37–39]. Not only that, STEM applications are also known to contribute positively to students' behavior, perspective, academic achievement, and scientific skills [40–42]. This STEM application carries the use of GPS in learning, which assuredly makes students actively involved in solving the problems they faced. As claimed by Berland and Steingut [43], learning with STEM applications aid students in constructing their abilities to think critically, creatively, and communicate effectively as well as to work together with one another to solve the challenges they face. In conclusion, it can be confirmed that the application of the STEM Autonomous Learning City Map generally has a positive impact on improving the critical thinking skills of students.

**Conclusion**

The researchers successfully developed the STEM Autonomous Learning City Map application. To sum up everything that has been stated so far, the result of validation by the media expert shows that the application is valid and appropriate to be used as a learning medium in the classroom. Then the output of the Paired Sample T-Test via SPSS reveals that there is an increase in the average score of the students' critical thinking skills after using the application in their learning. Therefore, it can be confirmed that the STEM Autonomous Learning City Map application has a positive effect on improving the critical thinking skills of PSTE students.

**Implication**

The implications of the findings of this study are a logical consequence of the development of the STEM Autonomous Learning City Map application learning media to improve the critical thinking skills of students majoring in PSTE. These implications can be divided into 2 categories; theoretical implication and practical implication. Theoretical implication in this study is that integrating technology and STEM into the learning process is beneficial and
worthwhile to increase students' knowledge that has been built in the previous lessons. Meanwhile, the practical implication is that the STEM Autonomous Learning City Map application also enriches efforts to upgrade the quality of learning in schools, specifically in critical thinking skills improvement. Applications make it easier for teachers to involve and encourage students to achieve learning objectives as well as train them to understand problems given and find solutions on their own.

**Recommendation**

The following recommendations are based on the empirical results of application testing which are proven to be practical to boost critical thinking skills. This recommendation is addressed to users and interested parties in improving the quality of education.

1. **For users**
   Users of the STEM Autonomous Learning City Map application are addressed to teachers. This learning application is an effort to provide new learning strategies for fun lessons. Conducting a learning process using media in the form of applications is very suitable and appealing for students at this time. Also, by learning this way, students have an active role in exploring their own knowledge in depth.

2. **For further researchers**
   This research can be another reference for further researchers who want to develop learning media in the form of applications or learning media related to STEM.

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