Development of Mathematics Learning Media Assisted by the MathcityMap to Improve Students' Critical Thinking Skills

Achmad Buchori
Universitas PGRI Semarang

Gebi Dwi Puspitasari
Universitas PGRI Semarang

The goal of this study was to create a new mathematics learning tool, leveraging the MathCityMap app and a contextual approach, to enhance critical thinking skills in trigonometry among students from the 10th grade of the SMA Laboratorium UPGRIS in the academic year 2021/2022. A random cluster sampling method was utilized to select participants. Data analysis revealed that both the test and control groups were evenly distributed and homogeneous. The t-test revealed no difference in average learning outcomes between the groups. Reviews from media and content specialists gave the learning tool validity scores of 85.2% and 83.6%, respectively, and the tool's appropriateness was rated as good with a score of 85.8%, which demonstrated its effectiveness. The N-Gain test score was 1.17, indicating successful achievement of the three learning effectiveness indicators. Increases of 0.61 and 0.52 were recorded for test and control groups, based on the N-Gain test, alongside satisfactory classical learning completeness. Data revealed that over 84.9% of students using the new math learning tool showed enhanced critical thinking capabilities.

Keywords: development, MathCityMap, critical thinking

INTRODUCTION

Mathematics is a basic arithmetic that every human being must master. All aspects of life use mathematics to obtain solutions to problems. Therefore, mathematics is the main subject at every level of education and various education majors. Over the years, Math subject has added study time to equip students to solve real-life problems reflected in the world of mathematics. In fact, according to the Regulation of the Minister of Education and Culture of the Republic of Indonesia in 2018, an additional four hours of lessons were added at the SMA/MA level in the Mathematics and Natural Sciences program to prepare Indonesian people to live as individuals and citizens who are faithful, productive, creative, innovative, and effective and can contribute to society, the nation, the state, and world civilization. Students are expected to learn mathematics to be productive in matters leading to mathematical critical thinking processes. the Regulation of the Minister of Education and Culture of the Republic of Indonesia No. 23 (2016) in the Content Standards for Primary and Secondary Education Units states that one of the goals of teaching mathematics in schools is that students demonstrate a logical, critical, analytical, careful, and thorough attitude, are responsible, responsive, and do not give up easily in solving problems[1].

Based on interview results with mathematics teachers at SMA LABORATORIUM UPGRIS, mathematics learning is conveyed to students, especially in trigonometric comparison materials, using learning media in the form of learning videos and textbooks. This kind of learning does not involve student participation, as students only focus on seeing and hearing the teacher's explanations. Teachers only instill mathematical concepts to the students without paying attention to whether they understand them. Learning is still primarily focused on books and less on contextual problems, while students are more interested in concepts related to contextual problems. There needs to be more attention given by the teachers to the high-level abilities of students. Students still need help developing critical thinking skills or higher-order thinking, especially in learning mathematics.

One factor that affects students' low critical thinking ability is the teacher's lack of tools or media to offer an overview of problem-solving. Therefore, some students need help solving problems in the material being studied. The teacher should present problems in learning and encourage the students to identify them, search for solutions, and present them. Students who can independently identify and apply a problem are actively developing their knowledge and skills. According to Wibowo (2016), students who are actively involved in the learning process can stimulate and develop their talents, practice critical thinking, and solve problems. It is not easy to take a critical thinker for granted. Instead, the ways of others are carefully scrutinized and used to obtain the most appropriate level of understanding. By thinking critically mathematically, students can identify problems and solutions for them.

Critical thinking is a systematic activity used by individuals to analyze and evaluate a problem based on their beliefs and opinions[2]. According to[3], thinking critically in mathematics helps students gain a deep understanding. According to[4], critical thinking in mathematics is one of the abilities students need to fully understand concepts, and apply, synthesize, and evaluate the information obtained. Critical thinking uses basic thought processes to analyze arguments, foster insight into specific meanings and interpretations, develop cohesive, logical reasoning, and understand certain positions, assumptions, and biases[5]. Critical thinking requires the ability to recognize, identify, and understand problems and find solutions to them. Students must have a good level of critical thinking to filter information, identify appropriate information, validate it, and follow up on the information used in their lives. Applying critical thinking skills in mathematics helps students understand mathematical concepts better because these skills help students analyze and evaluate. Critical thinking ability in learning mathematics includes activities to re-examine answers, analyze why problems arise, and interpret them.

The ability of Indonesian students to apply critical thinking in mathematics is low. Research conducted by[6] showed that the critical thinking skills of 21%, 64%, and 15% of high school students were moderate, low, and very low, respectively. Based on an international study on the mathematics achievement of Indonesian students in 2015, the Trend in International Mathematics and Science Study (TIMSS) showed that Indonesia ranked 44th out of 49 countries, with an average score of 397 out of an international average score of 500[7]. This downgrade from the 2011 TIMSS results, where Indonesia ranked 38th out of 42 countries. Meanwhile, in 2018, data from the Program for International Student Assessment (PISA), initiated by the Organization for Economic Co-operation and Development (OECD), placed Indonesia in 73rd out of 79 countries with an average score of 386 (the average OECD was 489)[8]. Indonesia's average score remains below the international average score, does not change much from year to year, and remains lower than the average score of other countries. The ability of Indonesian students to think critically in mathematics cannot be compared with students from other countries, especially with neighboring countries such as Singapore. The low index of students' mathematical critical thinking skills in Indonesia concerns researchers. An appropriate learning approach is needed to improve students' mathematical critical thinking skills. Another aspect that affects the ability to think critically in mathematics is the development of technology following the times.

Learning media is a tool used by teachers to deliver the subject matter to students. This is in line with Oemar Hamalik's understanding that learning media is a tool used to encourage effective communication and interaction between teachers and students during the educational process[9]. Teaching methods and teaching media are two important and interconnected elements of the teaching and learning process. Using media in learning can help students improve their understanding, help present data interestingly and

reliably, facilitate data interpretation, and condense information. Therefore, the benefits of learning media in the learning process are as teaching aids. The rapid development of learning media, such as teaching materials and learning software, help students in the learning process. This study employs a website to support the learning process. The selection of a website-assisted learning media is due to the ease of accessing information remotely, anytime, and anywhere via the internet. In addition, the rapid development of information technology allows many parties to update the content of teaching materials and other components so that students can be informed easily and quickly about scientific developments. Using a website as the learning media encourages students to be interactive and able to think creatively. This is known as a contextual approach.

[10]states that the contextual approach is a learning concept that presents real situations in daily life and brings them into a classroom setting. This motivates students to make connections between their knowledge and apply it in everyday life situations. Using a contextual approach makes it easier for students to understand the material because students can connect different things that already exist and compare them with phenomena that exist in the environment. In this way, new ideas or views emerge. A contextual approach can also help teachers relate the material to the students. An application that helps students relate learning material to real-world situations is the MathCityMap application. The MathCityMap is a project of the MATIS 1 working group of the Goethe-University Frankfurt am Main Institute for Mathematics and Informatics Education. An advantage of the MathCityMap application is that it encourages passionate learning from the students and reduces their boredom because learning is presented as a game. Games are an effective way to increase student's interest and ability to learn using learning media assisted by MathCityMap with a contextual approach to trigonometric comparison material, it can be presented with various attractive displays that illustrate examples of real-life problems in the form of learning media. This design can assist in solving problems of trigonometric comparison formulas that are attractively packaged, easier to understand, and less abstract.

Based on the description above, researchers are interested in researching and developing mathematics learning media with a contextual approach that can improve students' critical thinking skills. This aim is summarized in the research title, "Development of Mathematics Learning Media with Contextual Approach assisted by MathCityMap Application to Improve Critical Thinking Ability of High School Students."

Subsection

Development

Development is a process used to develop and validate educational products. Development can be in processes, products, and designs[11, 12]. Research and Development Methods, or in English "Research and Development," is used to produce specific products and test their effectiveness[13].

According to [14], the primary purpose of research and development in education is not to formulate or test theories but to develop products generated by research and development, including materials, media, and management systems. As a result, school administrators, as consumers of research and development efforts, may recognize the value of educational research for the first time.

Based on the opinion of experts, development research is a method to produce new products or improve existing products and must contain valid, practical, and effective criteria.

Learning Media

According to [15], media functions as a visual aid by providing visual experiences to students. This encourages motivation, makes abstract concepts easier to understand, and enhances students' concentration.

Learning media is a tool used during the learning process to convey messages to establish a good learning process[16]. Meanwhile, according to [1], using learning media in the teaching and learning process can generate new desires and interests, motivate and stimulate learning activities, and psychologically affect students.

Based on the experts' opinions, it can be concluded that media learning in mathematics is a tool used during the learning process to generate new desires and interests, generate motivation, and stimulate learning activities, to achieve the expected learning objectives.

MathCityMap

MathCityMap is a project of the working group MATIS 1 of the Goethe-University Frankfurt am Main Institute for Mathematics and Informatics Education. MathCityMap is an Android/iOS application based on GPS. MathCityMap provides locations/findings of mathematical problems in the Math Trail that will be used as points for the problems students will solve [17].

The MathCityMap project is based on the concept of a mathematical trace. Mathematical traces are paths to discovering mathematics [18]. Walkers (students) explore mathematics by following a planned route and completing outdoor math tasks related to what they encounter along the way. It is built to develop an appreciation and enjoyment of mathematics [19]. In the MathCityMap, sites with math challenges are localized by GPS [20]. In addition, these tasks are embedded in manual or digital city maps so that students can access them using a manual set or a GPS-enabled mobile application [21].

The MathCityMap application has several advantages; it motivates students to learn and reduces boredom experienced during learning because lessons are presented in a game form. However, the MathCityMap application also has drawbacks; the application is highly dependent on an internet connection. Therefore, a stable internet connection is needed to avoid disrupted learning [22].

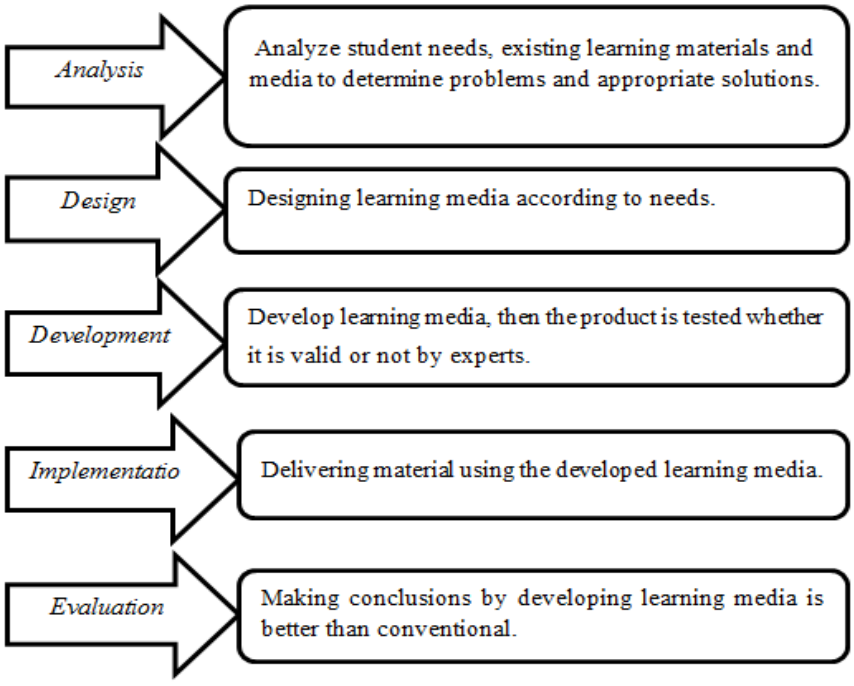
Critical Thinking Skills

Critical thinking ability is a process of using thinking skills effectively and systematically, allowing students to formulate and determine their beliefs and evaluate their decisions appropriately [23].

METHODS

The study utilizes a Research and Development research method where certain products are produced, and the effectiveness of these products is tested[24]. The particular research model used was the ADDIE model. This model consists of five main phases or stages, namely (A) analysis, (D) design, (D) development, (I) implementation, and (E) evaluation. The five phases or stages in the ADDIE model need to be carried out systematically and systematically. The ADDIE research method is illustrated in Figure 1.

FIGURE 1
ADDIE RESEARCH MODEL



RESULT AND DISCUSSION

This research was conducted using the ADDIE model. Following the stages contained in the ADDIE model, the research results are divided into five stages, namely: (1) Analysis Phase (Analysis), (2) Design Phase (Design), (3) Development Phase (Development), (4) Implementation Phase (Product Trial), (5) Evaluation Stage (Evaluation)

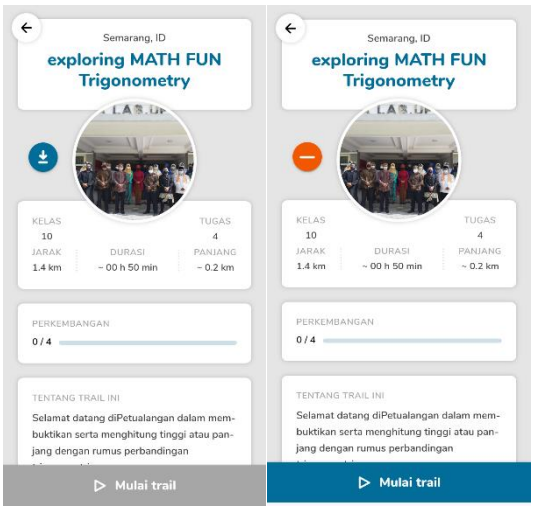
At each stage mentioned above, the essence of the research results will be further elaborated at the end of this report. The following is an explanation of each stage:

1. **Analysis**. The analysis stage is the initial stage carried out by researchers in the development of this learning media. The analysis in this study consists of performance and needs analysis.
    a. *Performance Analysis*. Performance analysis is carried out by conducting a preliminary study to identify problems and to determine the right solution to these problems.
    The researcher conducts a preliminary study by visiting the school that will be used as a research location, the UPGRIS Laboratory High School. Then, the researcher conducted an interview via WhatsApp with one of the mathematics learning teachers of class X. Based on the interview results, the following problems regarding poor learning in mathematics at SMA Laboratorium UPGRIS is that the delivery of material still uses media in the form of learning videos, textbooks as learning references and conventional learning methods, so students only listen and tend to be passive which makes students less active in class.
    Therefore, solutions are needed in mathematics lessons to facilitate the student's understanding of the learning material and improve their thinking skills. Learning media encourages students to participate in the learning process. For this reason, the researchers developed an interesting and innovative mathematics learning media using the MathCityMap application. This application directed students' mindsets to search for new knowledge, and that improves their critical thinking skills.
2. **Needs Analysis**. Needs analysis incorporates the analysis of the student's needs, curriculum analysis, and material analysis.
    a) *Analysis of Student Needs*. Analyzing student needs involves collecting and interpreting data regarding what students need. Observation results show that students need innovative, engaging, and practical learning media that can assist in the learning process to make it easier to understand mathematics learning materials. Therefore, the researchers developed mathematics learning media assisted by the MathCityMap application as an exciting and innovative learning medium.
    b) *Curriculum Analysis*. Curriculum analysis identifies the curriculum applied in schools and uses it as a reference when developing the learning media. For example, after making observations at the UPGRIS Laboratory High School, the 2013 curriculum was used.
    c) *Material Analysis*. Based on the 2013 mathematics curriculum from class X, one of the materials studied was the trigonometry comparison in right triangles.
3. **Design**. Researchers designed mathematics learning media using the MathCityMap application. The design of this product was as follows:
    a) *Title Page*. The title page design was based on the appearance of the MathCityMap application. In addition, there is a "trail or private session" page where the code for the trail or group session, provided by the teacher, can be entered.

FIGURE 2
THE MATHCITYMAP LEARNING MATERIAL TITLE PAGE

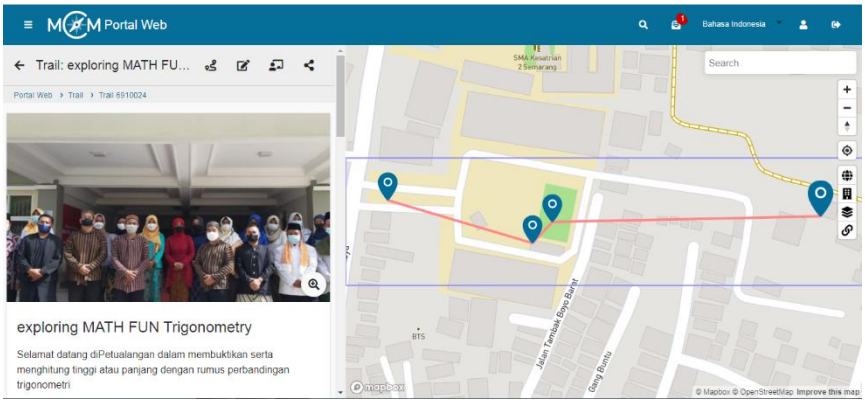
b) *Main Menu Page*. The main menu page display is designed using pictures of teachers and employees of the UPGRIS Laboratory High School to show that the characteristic context used in this study is the school. This section contains information and trail instructions. The information, such as distance, duration, trail length, and tasks or trails that must be completed, informs users about the trail. In addition, there is a "Start Trail" button which, when pressed, will go directly to the trail page.

FIGURE 3
THE MAIN MENU PAGE DISPLAY OF THE MATHCITYMAP LEARNING APPLICATION.



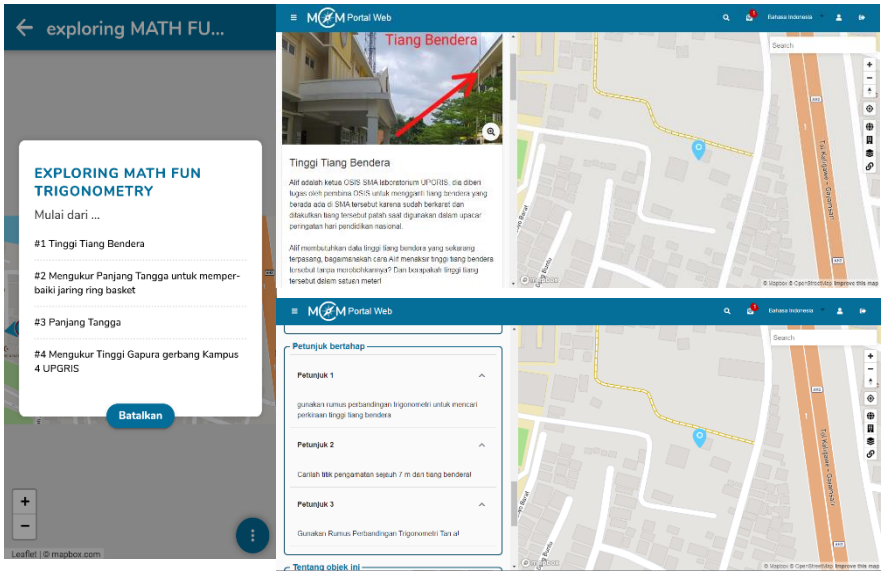
c) *Map Page*. On the map page display, there is an image of a map around the Laboratory High School and UPGRIS 4 Campus indicating the trail location. Students can use this to complete the assignments. In addition, students can choose which task they want to complete first by selecting it from a menu.

FIGURE 4
THE MAP PAGE INDICATING THE TRAIL LOCATION OF THE SELECTED TASK.



d) *Assignment Page (Trail)*. On the task page, the display contains four questions and pictures related to contextual learning or real-world situations. In addition, there is a hint button to assist students in completing assignments or trails. Each task contains two or three hints. The purpose of this task is for students to measure their abilities directly because they can see the scores obtained after completing all assignments or trails. In addition, the scores obtained can be used as a reference for students in learning.

FIGURE 5
TASK PAGE (TRAIL)



4. **Development Stage**. In the development stage, the researcher designs the learning media, which is then validated by media and material experts. Finally, the validation and assessment results of each learning media aspect are submitted to experts for further evaluation. The validation results are displayed in Table 1.

TABLE 1
LEARNING MEDIA EXPERT ASSESSMENT VALIDATION RESULTS

No	Assessment Aspect	Observation Score		Maximum Score	Appropriateness	
		I	II		I	II
1	General	19	17	20	95.0%	85.0%
2	Design	38	36	45	84.4%	80.0%
3	Content	23	22	25	92.0%	88.0%
4	Language	12	12	15	80.0%	80.0%
5	Media Practical	18	16	20	90.0%	80.0%
	Total Score	110	103	125	88.0%	82.4%
Final Percentage					85.2%	

The five aspects of the MathCityMap mathematics learning media, including general (90%), design (82.2%), content (90%), language (80%), and media practicality (85%), were rated as very good or decent criteria after the validation and assessment by experts.

The next development product submitted to learning material experts to be validated is a mathematics learning media with a contextual approach assisted by the MathCityMap application oriented to the critical thinking skills of high school students. The results of the validation and assessment are presented in Table 2.

TABLE 2
VALIDATION RESULTS OF LEARNING MATERIAL EXPERT ASSESSMENT OF THE MATHEMATICS LEARNING MEDIA WITH A CONTEXTUAL APPROACH

No	Assessment Aspect	Observation Score		Maximum Score	Appropriateness	
		I	II		I	II
1	General	19	16	20	95.0%	82.0%
2	Material Substance	61	56	70	87.0%	80.0%
3	Use of Language	12	12	15	80.0%	80.0%
4	Learning Design	17	16	20	85.0%	80.0%
	Total Score	109	100	125	87.2%	80.0%
Final Percentage					83.6%	

Table 2 clearly shows that the five aspects of the mathematics learning materials, general (88.5%), material substance (83.5%), language use (80%), and learning design (82.5%), were rated as very good or decent criteria by material experts.

5. **Implementation**. This stage is the implementation of the product that has been tested for feasibility. Any required revision is carried out on the mathematics learning media, which is then tested in learning. Initial evaluation questions were tested in the trial class to obtain valid questions, then valid questions were used as evaluation questions at the end of the study (post test).The ten questions used in the trial were related to the comparison of trigonometry in right triangles. Class XI from MIPA SMA Laboratorium UPGRIS, who had received trigonometry comparison material, took part in the trial.
6. **Evaluation**. The last stage of development of the mathematics learning media assisted by the MathCityMap application is the evaluation stage. This stage determines the feasibility of the developed mathematics learning media. The right-hand t-test was used to determine whether the average learning outcome of the experimental class was better than the control class. This test also determines the effectiveness of the learning media product. The criteria for the right-hand t-test for the average learning outcomes of the experimental class are better than the

control class $t_{hitung} > t_{tabel}$. The right-hand t-test was used in this study with a significance level of 5% (Table 3).

TABLE 3
T-TEST RESULTS TWO-PARTY RIGHT FINAL DATA

Class	n	t_{hitung}	t_{tabel}	Conclusion
Experiment	28	1.80	1.67	The average critical thinking ability of the experimental class is better than the control class
Control	28			

Based on these calculations, the average critical thinking ability of the experimental class is better than the control class.

The N-Gain test was carried out after the pre-test and post-test scores from the experimental and control class. The purpose of the N-Gain test is to determine whether or not there is an increase in students' critical thinking skills between the two classes (Table 4).

TABLE 4
CONCLUSION OF N-GAIN RESULTS

No.	Class	N-Gain	Category
1.	Experiment	0.61	Medium
2.	Control	0.52	Medium

The critical thinking skills of the experimental and control class are classified as medium by the N-Gain classification system (medium category score ranges from 0.3 to 0.7). Therefore, from the described categories, the normal gain of the experimental class is higher than the control class in the same category.

Based on the average score, the improvement in the critical thinking skills of the experimental class students is better than the critical thinking skills of the control class students.

Completeness of Student Learning Outcomes

Completeness of student learning outcomes is used to determine the learning using the mathematics learning media with a contextual approach assisted by the MathCityMap application. Mastery learning outcomes are divided into individual learning completeness and classical learning completeness.

Individualized Learning Mastery

The average student learning outcomes of the experimental and control class using the mathematical realistic learning model-based Mobile Learning media can be seen in Table 5 below:

TABLE 5
INDIVIDUAL LEARNING MASTERY TABLE

Total Students = 20	Control Class	Experiment Class
Complete	19	24
Not Complete	9	4

Classical Learning Completeness

This test is used to determine whether student learning outcomes achieve classical completeness. A class is said to have completed classical learning if there are students who complete the class. The results

of calculating the percentage of classical learning completeness for the experimental and control class was 85.71% and 67.86%, respectively. Classical Learning Mastery is also determined using the left-hand t-test (Table 6).

TABLE 6
CLASSICAL LEARNING COMPLETENESS

Class	N	t_{hitung}	t_{tabel}	Conclusion
Experiment	28	4.63	1.70	The proportion of complete student learning outcomes is achieved
Control	28	1.17	1.70	The proportion of complete student learning outcomes is not achieved

Based on the data from the experimental class (n = 28, significant level of 5%), and sign > 0.05, therefore the H_0 is accepted. For the control class (n = 28, significant level of 5%), a t_{hitung} and t_{tabel} value of 1.17 and 1.70, respectively means that $t_{hitung} < t_{tabel}$, therefore the H_0 is rejected. Based on these calculations, the proportion of student learning mastery is achieved in the experimental class but not in the control class.

CONCLUSIONS

Based on the results of the analysis and discussion in this study, it can be concluded that:

1. The development of a mathematics learning media with a contextual approach assisted by the MathCityMap application oriented to improve the critical thinking skills of high school students, is valid (feasible) to be used.
2. This mathematics learning media is practical. Student questionnaires showed that the percentage of the appropriateness of this mathematics learning media application was 85.78%.

This mathematics learning media is effective. For example, the N-Gain test results obtained were 1.17, and the critical thinking skills of the students who used this application exceeded 80%.

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