The Effectiveness of Learning Tools Based on Discovery Learning That Integrates 21st Century Skills to Mathematical Critical Thinking Ability in Trigonometric Materials in High School

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Abstract. This study aims to determine the effectiveness of discovery learning based learning tools that integrate 21st-century skills in trigonometric material on the mathematical critical thinking skills of students in high school. This research is a pre-experimental study with a one-group pretest-posttest design. The tools used are the syllabus, lesson plans, and student’s worksheets. The learning tools used have gone through the validation process and previous practicality tests. The effectiveness test was conducted in class XI MIPA 1 SMA Babussalam Pekanbaru. In the effectiveness test stage, the researcher gave a mathematical critical thinking ability test after completing the learning using the developed device. Indicators of mathematical critical thinking skills used are interpretation, analysis, evaluation, verification and inference. The test results show that there is an increase in each indicator of critical mathematical thinking used and the percentage of students who reach the passing grade test of mathematical critical thinking skills reaches 82.14%. So it can be concluded that the learning tools developed are effective for use. The data obtained from the critical thinking skills test results were not normally distributed based on the normality test, so to find out differences in students’ critical thinking skills before and after using the device, researchers used the Mann Whitney test. Based on the results of the Mann Whitney test, it is known that the mathematical critical thinking skills of students after using the device are better than before using the device with an N-Gain value of 0.70 with a high increase category.

1. Introduction
The role of mathematics is very important in shaping and developing thinking skills. One focus of learning in SMP and SMA according to the Ministry of National Education is the development of mathematical critical thinking skills and this ability is also one of the graduation standards for students. SMP and SMA graduates are expected to have the ability to think logically, analytically, systematically, critically, and creatively as well as the ability to work together. But in reality, based on Eny Sulistiani’s research [1] the implementation of mathematics learning in schools has not maximally trained students’ critical thinking skills. This is supported by the results of research by Lilis et al. [2] which states that students’ critical thinking skills are still low. The facts show that the ability to think critically and its development still requires great attention in the world of education.

Critical thinking skills are often improved in implementing the learning process. This is because the process of developing critical thinking skills takes a long time. Roby [3] said that if the success of
the educational process is not focused on critical thinking skills, students will find it difficult to continue at the next level, especially at the university level. As we all know that the learning process at the university level is not the same as at school. Students are required to be more active and more independent in learning. If critical thinking skills are not trained, students will have difficulty identifying a complex problem. This is what will make it difficult for students to analyze a problem to its resolution.

In line with Roby's opinion, In Hi Abdullah [4] explained that a highly capable person must be able to think logically, rationally, critically, and creatively. Therefore students need to develop critical thinking skills so that they can face challenges and progress in the era of globalization. By having the ability to think critically, it is hoped that students will be more productive to survive and develop in the 21st century.

Entering the 21st century, challenges in all aspects of life will be even greater. Therefore, the quality of human resources is needed. This means that to create quality human resources, students must have the skills needed to answer the challenges in the 21st century. This is in line with Trilling and Fadel's opinion [5] that the biggest challenge of education in the 21st century is to prepare students to contribute. One of the 21st-century skills that students must have is the ability to think critically. Ratna [6] states that critical thinking skills include the ability to access, analyze, synthesize information that can be learned, trained, and mastered. In critical thinking skills also describe other skills such as communication and information skills, as well as the ability to examine, analyze, interpret, and evaluate.

A survey conducted by the World Economic Forum (WEF), shows that Indonesia's 2016-2017 Global Competitiveness Index (GCI) is ranked 42 out of 138. This is due to the education level of Indonesian workers which affects their critical power and analytical thinking skills. Based on this, it can be seen that the ability to think critically is very important to be cultivated from the start, both at school, at home and in the community to prepare quality generations.

Based on the opinions of the experts above, mathematical critical thinking is a complex thought process to find solutions and solve mathematical problems by analyzing and evaluating existing information. Thus it can be seen that mathematical critical thinking skills are very important to instill in students. But in reality, this critical thinking ability has not been practiced often in schools as expressed by Jacqueline and Brooks quoted by Ali Syahbana [7]. Schools direct students to give correct answers rather than train students to come up with new ideas to analyze existing answers. As a result, many students who passed could not think deeply, only standing on the surface of the question.

Many things affect the quality of graduates, one of which is the implementation of learning in schools. The process of implementing mathematics learning and its evaluation at this time is more training students in procedural skills through routine problem exercises and low-level questions. In other words, students are only trained in low order thinking skills [8]. Research Liberna [9] shows the low ability of students to think mathematically critical because learning is still done in one direction. Based on the research results above, the mathematical critical thinking ability is still not optimal, so it needs to be improved.

Increasing critical thinking skills also supports the Partnership for 21 Century Learning program, which states that there are four skills that students must possess. These skills are known as 4Cs, namely critical thinking, creativity, communication, and collaboration. These four skills can help students compete and survive to face global challenges [10]. These 4C-based skills have been widely adopted by the education systems of several countries in the world, and it is evident that their TIMSS and PISA ratings are far above. This needs to be a major concern in learning mathematics in Indonesia in the future to improve the quality of education.

In terms of improving the quality of education in Indonesia, the government has made several policies, one of which is implementing the 2013 Curriculum. The Ministry of Education and Culture No. 20/2016 on Graduates Competency Standards (SKL) explicitly states that graduates must have thinking and acting skills: 1) creative, 2) productive, 3) independent, 4) critical, 5) collaborative, and 6) communicative. This indicates that the purpose of education in Indonesia has anticipated the demands of life in the 21st century, namely to create graduates who not only have 4C skills but are also productive and independent.
According to the Ministry of Education and Culture No. 103 of 2014 [11], in primary and secondary education the Learning Implementation Plan (RPP) in the 2017 revised edition of the 2013 Curriculum must integrate four things, namely Strengthening Character Education (PPK), literacy, 21st-century skills (critical thinking), creativity, communication, collaboration), and the High Order of Thinking Skills (HOTS). The implementation of the 2017 revised edition of the 2013 Curriculum which integrates 21st-century skills demands the pedagogical ability of teachers in designing mathematics learning tools, where these learning devices will be implemented in the learning process.

According to Nancy [12], based on 350 questionnaire data from primary, secondary education teachers and lecturers in various regions in Indonesia, it was found that only 35% could explain 21st-century skills and only 17% were able to design, implement and access learning that emphasized 21st-century skills. 21st-century skills are in line with the 2013 curriculum, so learning tools that integrate 21st-century skills are needed to support the successful implementation of the 2013 curriculum. However, the lack of use and arrangement of learning tools that integrate 21st-century skills makes it difficult for teachers to design these learning tools themselves.

In line with Nancy’s research, the results of observations by researchers at SMA Babussalam Pekanbaru also show that the tools used by teachers have not integrated 21st-century skills. Besides, teachers have difficulty developing lesson plans that are following the 2013 curriculum. This is because teachers do not understand and cannot implies the models, strategies, methods, and approaches suggested to meet the demands of the 2013 curriculum that integrates 21st-century skills. Teachers still have difficulty making assessment plans that are translated into lesson plans.

The learning resources are in the form of books, namely mathematics textbooks published by the government. The teacher has implemented group learning in the learning process. During the learning process, the group sitting at the front seemed to participate well in the lesson, while some of the groups sitting at the back still did not participate optimally. Even though in group learning it is expected that all students help each other in learning. Students also do not discover the concept of learning by themselves but apply the concepts that have been explained by the teacher.

In group learning, the student’s worksheets used is the worksheets published by Intan Pariwara whose contents are material summaries and practice questions. In addition to the Intan Pariwara worksheets, the teacher also provides the worksheets that the teacher compiled. The worksheets that use contain practice questions, not steps that must be taken by students in constructing their knowledge so that students do not feel challenged to build r own knowledge from the material being studied and do not train students’ mathematical critical thinking skills. It can be said that the existing mathematics learning tools have not been developed optimally.

In the era of globalization, teachers should motivate, encourage, and facilitate students in constructing their knowledge in the learning process. However, teachers are no longer the main source of learning. To assist students in constructing their learning concepts, discovery learning models can help transform learning into student-centered (student-centered learning). Wulandari [13] stated that learning using the discovery learning model will provide good results by itself. Students try on their own to find solutions and solve problems with a meaningful learning process. Through the stages in the discovery learning model, students learn actively with the concepts and principles so that students gain experience and provide opportunities to conduct experiments so that students can find the principles themselves. The knowledge and concepts acquired last a long time when compared to knowledge learned in other ways.

Based on the expert opinion above, learning with discovery learning model is very good when applied in the learning process. This is because by applying the discovery learning model, students will construct their knowledge and try to find concepts from the learning that is being carried out. In applying the discovery learning model, the teacher acts as a guide and facilitator. Students are allowed to find and construct their learning concepts. This is consistent with the characteristics of discovery learning proposed by Hosnan [14]. “The main characteristics of learning to discover, namely (1) exploring and solving problems to create, combine and generalize knowledge; (2) learner-centered; (3) activities to combine new knowledge and existing knowledge ”. So by applying discovery learning, students will further explore their abilities.
One of the subject matters that can train students to find and construct their knowledge is trigonometric material. Trigonometry is a subject matter in class X semester 2 of the 2013 curriculum. In the research of Khusnul Khotimah et al. [15], it is known that trigonometry is a material that is difficult for students to understand and learning outcomes are still very low. This is because students' understanding of this material, students tend to memorize and are not directly involved in the discovery of the concept of trigonometry.

In Teguh Prasojo's research [16] it is said that the difficulty of students in understanding trigonometric material is due to a large number of formulas and the lack of practice on trigonometric questions. In studying trigonometry, students only accept existing formulas, then memorize them. This makes students accustomed to only accepting and not being trained to develop critical thinking skills. In studying trigonometric material, students are highly required to have mathematical critical thinking skills. By training students to think critically on this material, students will indirectly construct their knowledge.

Based on the description of the learning process, the importance of learning tools, and the low mathematical critical thinking skills of students, a way is needed to overcome this. One way that can be done is to determine the effectiveness of discovery learning-based learning tools that integrate 21st-century skills with mathematical critical thinking skills in trigonometric material in high school.

2. Methodology

This type of research is a pre-experimental study with a one-group pretest-posttest design. The test subjects were students of class XI Science 1 SMA Babussalam Pekanbaru for the 2019/2020 school year which consisted of 28 students. In this study, the influence between the two variables will be sought. The first variable is the discovery learning model that integrates 21st-century skills and the second variable is the students' mathematical critical thinking ability on trigonometric material. The one-group pretest-posttest design research design pattern is an experiment that is carried out in one group only without a comparison group. This design can be shown in Table 1 below.

| Table 1. One Group Pretest-Posttest Design |
|-------------------------------------------|
| Pre-test | Treatment | Post-test |
| O₁       | X          | O₂        |

The learning tools used were in the form of syllabus, lesson plans, and student worksheets which have been through the validation process by 3 validators and practicality tests. The practicality test itself consists of a limited test to see the readability of the device and a field test to see the practicality of the device. Furthermore, the revised device will be tested on an effectiveness test to see its effectiveness. The learning device is said to be effective if the percentage of students who reach the classical completeness criteria is 75%. To determine the percentage of classical achievement, the researcher used the following formula.

\[
Percentage = \frac{\text{The number of students who passed}}{\text{Total students}} \times 100\% 
\]

To see differences in students' mathematical critical thinking abilities, researchers used test results. The criteria for increasing the mathematical critical thinking ability indicators are based on Table 2 below.

| Table 2. Criteria for Increasing Mathematical Critical Thinking Ability Indicators |
|----------------------------------------|
| Percentage | Category |
| 81,25 \( < x \leq 100 \) | Very High |
| 71,5 \( < x \leq 81,25 \) | High |
| 62,5 \( < x \leq 71,5 \) | Medium |
5

\[
43.75 < x \leq 62.5 \quad \text{Low}
\]
\[
0 < x \leq 43.75 \quad \text{Very Low}
\]

The test results were analyzed using the normality test first. Followed by a non-parametric statistical test, namely the Mann Whitney test because the data tested were not normally distributed. To see an increase in mathematical critical thinking skills, researchers used the N-Gain test in the following way.

\[
g = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{max}} - S_{\text{pre}}}
\]

Note:
- \(g\) : N-Gain
- \(S_{\text{post}}\) : Posttest Score
- \(S_{\text{pre}}\) : Pretest Score
- \(S_{\text{max}}\) : Maximum Score

The N-gain value was interpreted using Hake's classification [17]. The classification of the increase based on the average N-gain value can be seen in Table 3 below.

| N-Gain Average Value | Increasing Classification |
|----------------------|---------------------------|
| \(g \geq 0.70\)       | High                      |
| \(0.3 < g \leq 0.70\) | Middle                    |
| \(g < 0.3\)          | Low                       |

3. Results and Discussion

3.1 Results

Learning devices that have passed the validation process and practicality tests are then tested on students in one class. The effectiveness test was conducted to see the effectiveness of the learning tools developed using pre-experimental research with a one-group pretest-posttest design. In this design, there is a group that is given treatment, to compare the conditions before and after being treated. The one-group pretest-posttest design used the initial test given before the start of the treatment, so there were two \(O_1\) pretest tests and \(O_2\) posttests. The following describes the results of the analysis of the effectiveness test.

The effectiveness of the developed learning tools is seen from the completeness of the test results of students based on the predetermined the passing grade of critical thinking ability, namely 70. Thus, students are declared complete if they get a value of \(\geq 70\). To see the achievement of the passing grade the researchers used the frequency distribution table as shown in Table 4 following.

| Interval | Frequency |
|----------|-----------|
| 40 - 49 | 1         |
| 50 - 59 | 0         |
| 60 – 69 | 4         |
| 70 - 79 | 6         |
| 80 - 89 | 16        |
| 90 - 100| 1         |
| Total number of students who reached | 23 |
Based on Table 4 it is known that 5 students did not reach the passing grade and 23 students reached the passing grade. This shows that the percentage of students who reach the passing grade after using the mathematics learning tools developed is 82.14%. So it can be concluded that the learning tools developed are effective for use.

The results of the students’ mathematical critical thinking ability tests before and after using the developed mathematics learning tools can be seen in Table 5.

| Max Score | Pre-test | Post-test |
|-----------|----------|-----------|
| Min Score | 10       | 47        |
| Average   | 28.21    | 78.64     |

| Average for each indicators (%) | Pre-test | Post-test |
|--------------------------------|----------|-----------|
| Interpretation                 | 70.37    | 95.02     |
| Analyze                        | 58.23    | 82.44     |
| Evaluation                     | 35.03    | 78.82     |
| Proofing                       | 23.47    | 56.77     |
| Inference                      | 21.70    | 48.07     |

Based on Table 5, it can be seen significantly that there is an increase in students' mathematical critical thinking skills between the pretest and posttest. The maximum value obtained by students at the time of the pretest was only 55. There was an increase in the maximum value obtained by students at the time of the posttest to 90. In line with this, the minimum score obtained by students at the time of the pretest also increased at the time of the posttest, namely from 10 to 47.

Increasing the value of students will certainly affect the increase in the average score of students from pretest to posttest. At the time of the pretest the average obtained by students was very low, namely 28.21. The average value of students increased at postest to 78.64. The results of the analysis of the mathematical critical thinking ability test to see differences in mathematical critical thinking abilities before and after the use of mathematics learning tools with discovery learning models begins with a normality test. The normality test is used to determine whether the data is normally distributed or not.

The results of the data normality test analysis of students' mathematical critical thinking skills before and after the use of learning tools used the Kolmogorov Smirnov test with SPSS 22.0. The hypothesis is:

\( H_0 \): The results of the mathematical critical thinking skills test before and after the use of normally distributed devices

\( H_1 \): The results of the mathematical critical thinking skills test before and after using the device were not normally distributed

The results of the calculation of the normality test are presented in Table 6 below.

| Test      | N  | Average | Sig. | \( H_0 \) |
|-----------|----|---------|------|----------|
| Pre-test  | 28 | 28.21   | 0.036| Rejected |
| Post-test | 28 | 78.64   | 0.001| Rejected |
Based on Table 6, the pretest and posttest significance level is 0.036 and 0.001 so that \( p < \alpha = 0.05 \). This explains that the mathematical critical thinking skills test data before and after are not normally distributed.

The difference test was performed using a non-parametric test, namely the Mann Whitney test because the data were not normally distributed. The results of the Mann Whitney test analysis were used to see the average difference in the students' mathematical critical thinking ability tests before and after using the learning tools. The results of the test for differences in students' mathematical critical thinking abilities before and after the use of learning tools used SPSS 22.0. The hypothesis is as follows:

\( H_0 \) : There is no difference in students' mathematical critical thinking skills before and after the use of learning tools.

\( H_1 \) : There is difference in students' mathematical critical thinking skills before and after the use of learning tools.

The results of the test for differences in students' mathematical critical thinking abilities before and after the use of learning tools are presented in Table 7 below.

| Table 7. Mann Whitney Test for Pretest and Postest of Mathematical Critical Thinking Ability Test |
|---------------------------------------------------------------|
| N    | Mean | Sig. | Conclusion |
|------|------|------|------------|
| Pre-test | 28   | 28.21| 0.000      | \( H_0 \) Rejected |
| Post-test | 28   | 78.64|            |                      |

Based on Table 7, for the pretest and posttest data, the mathematical critical thinking ability obtained \( p = 0.000 \). The significance level is \( p < \alpha = 0.05 \), so it can be concluded that \( H_0 \) is rejected and \( H_1 \) is accepted. Based on this, it can be said that there are differences in students' mathematical critical thinking skills before using learning tools (pretest) and after using learning tools (posttest).

The N-gain score to see the increase in students' mathematical critical thinking ability scores before and after using discovery learning model-based learning tools by integrating 21st century skills. Based on Table 4, the average pretest score is 28.21 and the posttest score is 78.64 so that the N-Gain value is obtained of 0.70. Based on the N-Gain score obtained, it is known that the increase that occurs is in the "high" category. The increase in the average posttest score shows that in general mathematics learning tools based on discovery learning models by integrating 21st century skills are effective in improving students' mathematical critical thinking skills after students use products in learning.

3.2 Discussion

After the use of learning tools with discovery learning models that integrate 21st-century skills, then a test to measure students' mathematical critical thinking abilities is carried out using a mathematical critical thinking ability test instrument. The effectiveness of product development is reviewed based on the test results of students' mathematical critical thinking skills. Based on the completeness of the students' critical thinking ability test results, the percentage of students who reached the passing grade after using the developed mathematics learning tools was 82.14%. Thus the learning device developed is effective for use because it has exceeded classical completeness by 75%.

From the results of the analysis of each indicator of mathematical critical thinking, there was also an increase as shown in Figure 1 below.
Figure 1. Results of the Mathematical Critical Thinking Ability Test for Each Indicator

Based on the diagram above, it can be seen that the increase in students’ critical thinking skills for each indicator through the results of the pretest and posttest. In the interpretation indicator, at the time of the pretest, the percentage was 70.37% in the medium category. At the time of the posttest, the percentage was 95.02% in the very high category, an increase of 24.65%. Interpretation indicators have increased because students already have initial abilities, making it easier to master new concepts. This is in line with Zulkarnain's research [18] that the increase in interpretation indicators is due to the strong initial abilities of students.

In the analysis indicator, when the pretest has obtained the percentage of 58.23% was in a low category. Meanwhile, at the time of the posttest, the percentage was 82.44%, which was in the very high category. Thus there was an increase of 24.21%. The increase in analysis indicators occurs because students are accustomed to analyzing as is done during learning activities in the data processing phase.

In the evaluation indicators, the pretest results obtained a percentage of 35.03% which is in the very low category. In the post-test results obtained a percentage of 78.82% who are in the high category. Thus there was an increase of 43.79%. Integrated evaluation indicators in data processing activities and data verification in learning activities. Students are trained to respond to this phase.

In the evidentiary indicator, through the pretest results obtained a percentage of 23.47% which is in the very low category. While the post-test results obtained a percentage of 56.77% who are in the low category. However, there was a significant increase of 33.3%. The increase in evidentiary indicators occurred because students began to get used to proving during learning activities in the verification phase. However, students still have difficulty in compiling the concepts they already have to show the truth of a statement.

In the inference indicator, through the pretest results obtained a percentage of 21.7% which is in the very low category. While the post-test results obtained a percentage of 48.07% who are in the low category. However, there was a significant increase of 26.37%. In the inference indicator, the increase occurs because students are trained to express conclusions at the generalization stage in learning activities. However, what students miss is accuracy. So that most students do wrong calculations which causes students to make wrong conclusions.

An increase in each indicator of mathematical critical thinking is supported because students are getting used to using active learning stages so that they are trained to think deeply and critically to construct their knowledge. This is supported by T. Jumaisyarah's research [19] which states that the increase in students' mathematical critical thinking skills occurs because the applied learning model
can trigger students to use their basic abilities to get solutions to solve the problems given. That way students get the opportunity to maximize their thinking skills.

Based on the test of differences in mathematical critical thinking skills in the normality test, it was found that the test data for mathematical critical thinking skills before and after were not normally distributed. Therefore, the researcher conducted a non-parametric test through the Mann Whitney test to see the average difference in students' mathematical critical thinking ability tests before and after using the developed learning tools. Based on the results of the Mann Whitney test, the significance level of \( p < \alpha = 0.05 \) is obtained. So it can be concluded that \( H_0 \) is rejected and \( H_1 \) is accepted. This means that there are differences in students' mathematical critical thinking skills before using the learning device (pretest) and after using the learning device (posttest). This shows that there are differences in students' mathematical critical thinking abilities before and after using discovery learning model-based learning tools by integrating 21st-century skills.

Based on the average N-gain obtained from the comparison of the pretest and posttest mean scores of mathematical critical thinking skills in using mathematics learning tools with discovery learning models that integrate 21st-century skills is 0.70 with the high category. It can be said that the device developed has had an impact on increasing students' mathematical critical thinking skills with a high level of improvement. Based on the results of this study, mathematics learning tools with discovery learning models that integrate 21st-century skills are effective to improve students' mathematical critical thinking skills on the material of the sine and cosine rules.

In line with Wahyu Setiawan's research [20] that there is an increase in students' mathematical critical thinking skills through guided learning with the discovery model compared to conventional learning. Leni Dhianti's research [21] also shows that discovery learning models can improve mathematical critical thinking skills. There is an increase in students' mathematical critical thinking skills after using discovery learning-based teaching materials.

Based on the completeness of the students' mathematical critical thinking ability test, it can be stated that the device developed with the discovery learning model that integrates 21st-century skills is effective for use and through the different test it is known that there are differences in students' mathematical critical thinking abilities before and after the use of the developed device. Through the N-Gain test, it is known that the device developed has an impact on increasing students' mathematical critical thinking skills.

4. Conclusion
Mathematics learning tools developed based on discovery learning models by integrating 21st-century skills on the sine and cosine rules material in high school have met the criteria of effectiveness in terms of completeness of students' mathematical critical thinking ability tests obtained after using the learning tools developed which is 82.14%. The developed mathematics learning tools can improve the mathematical critical thinking skills seen from the results of the Mann Whitney test. namely the level of significance \( p < \alpha = 0.05 \). So it can be concluded that \( H_1 \) is accepted or there is a difference in students' mathematical critical thinking skills between before using the developed learning tools and after using the developed learning tools. The average N-gain obtained from the comparison of the pretest and posttest mean scores of mathematical critical thinking skills in using mathematics learning tools with discovery learning models that integrate 21st-century skills is 0.70 with the high category.

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