Students’ critical mathematical thinking abilities through flip-problem based learning model based on LMS-google classroom

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Abstract. This research aimed to calculate the increase of students’ mathematics critical thinking ability in Senior High School who taught with Flip-Problem Based Learning based on LMS- Google Classroom. This research is quasi-experiment research used pre-test post-test control group design research. Sample in this research is 60 students divided into two research groups, 30 students in the experiment group (taught with Flip-Problem Based Learning) and 30 students in the control group (taught with Problem-Based Learning). The homogeneity test and normality data test used Levenes’ test and Kolmogorov Smirnov test. The result of the homogeneity test and normality data test is homogenous and distributed normally. Based on the result of the homogeneity test and normality data test, hence the hypothesis research test used Independent Sample T-Test. The test result showed that mathematical critical thinking ability for students’ Senior High School who taught with Flip-Problem Based Learning based on LMS-Google Classroom. The result proved that the mathematics learning process of Flip-Problem Based Learning has a positive and significant effect on students’ mathematics critical thinking ability. Based on this research result, Flip-Problem Based Learning was recommended to be applied in mathematics learning. LMS-Google Classroom can also be one of the solutions in mathematics learning based on digital.

1. Introduction
Mathematical learning is inseparable from learning that focuses on solving mathematical problems, especially related to contextual problems [1–3]. This is supported by a statement on the learning objectives of mathematics in the 2013 curriculum which emphasizes the modern pedagogical dimensions using a scientific approach. Mathematics learning also emphasizes authentic learning in which the ability to observing, asking, trying, reasoning, serving and creating of the students is developed [4,5]. The National Council of Teachers of Mathematics also explained a similar thing, in which the aim of mathematics learning emphasizes the ability to understand, communication skills, problem-solving skills, the ability to integrate ideas into various problems, critical thinking skills, to the ability to think mathematically creative thinking [6,7]. Based on these two perspectives regarding the objectives of mathematics learning, mathematics educators must focus on increasing these mathematical abilities hence they can later be used meaningfully in the process of solving contextual problems. In this study, researchers focus on improving students' critical thinking skills.

This is one of the problems that are quite complex, considering that students still experience difficulties in the process of thinking critically about mathematics learning. One indicator of the weakness of students' abilities, especially students' critical thinking skills, is seen from the students' initial ability scores which are still in the low category [8,9]. This is also consistent with the results of
the Program for International Students Assessment (PISA) in 2018, obtained that the average student in an OECD country (73% of students at level 2) have difficulty understanding critically and interpreting contextual issues correctly [10]. A similar thing was obtained by Trends in International Mathematics and Science Study in 2015 that students had difficulty understanding contextual and open-ended problems [11]. In their study, Maričića and Špijunović also have shown that selection of content can make a significant contribution to the development of students’ critical thinking skills in elementary mathematics education, this can be achieved by all of students, regardless of their overall academic achievement of students, especially high school student in contextual mathematics learning [12]. Critical thinking is heavily reliant on the topic and content. Students have problems in coping with topics and content material that involve a problem analysis and a process of how to solve problems, particularly non-routine problems. This is achieved by evaluating teachers’ selected subjects, the tasks that their students had to complete, and how they directly linked these tasks to the development of critical thinking. In terms of the subjects that have been chosen, teachers should prefer topics that relate to the core aspects within their subject (mathematics) as well as to issues of the real world. The most common activities needed students to analyze, inquire and come up with ideas. [13].

Critical thinking is defined as a way to determine a reasonable decision or judgment regarding any statement or problem raised related to being false, true or only partially true [14–18]. In the context of mathematics learning, critical thinking increases creative problem-solving choices, because it can encourage students to find new strategies in solving problems [19]. The development of critical thinking skills will improve the ability of students’ brains to think logically, structured and appropriate in solving mathematical problems and must be oriented to true and rational perceptions. Students with high mathematical critical thinking skills can organize between concepts to solve problems [20,21]. Indicators of critical thinking skills used in this study can be seen in Table 1 [22].

Table 1. Indicators of critical thinking ability

| Indicator | Indicator Description |
|-----------|-----------------------|
| Interpretation | Understand the problem shown by writing the known and the asked questions correctly. |
| Analysis | Identify the relationships between statements to statements, statements to questions, concepts to concepts by making mathematical models correctly and presenting appropriate explanations. |
| Evaluation | Using the right strategy in solving problems, complete, and correct in doing calculations. |
| Inference | Can draw conclusions from what was asked correctly. |

There were limited research on the specific strategies that most effectively help students to develop critical thinking. Fung underlined that the influence of instruction is often overlooked in studies that examine critical thinking amongst other student [23]. Rodzalan & Saat found that throughout this time, the teaching and learning process in the classroom, which emphasizes rote learning and focuses so much on content, let students memorize knowledge that they have learned rather than evaluate and synthesize the actual sense of knowledge [16]. Because they do not have a clear understanding of the skills they have gained, it contributes to a decline in their ability to think objectively and to solve complex problems. Aizikovitsh & Amit also found that research connect to critical thinking skill does not pressure on daily contextual problem [24].

Improving students’ critical thinking skills needs to be supported by learning that is encouraging students to explore mathematical problems to be solved. The necessary learning also needs to encourage students to be able to carry out group investigations, integrate concepts that have been obtained previously and scaffolding strengthening processes are necessary. The learning process offered in this study is learning that is a combination of digital-based learning (online learning) and face-to-face learning. Digital-based learning uses the assistance of the Learning Management System (LMS) with the type of Google Classroom that is easy for students and teachers to use. Besides, LMS-Google
Classroom can also be used anywhere and at any time either through the mobile or device of each student or through a Laptop or PC Desktop [25–27]. Display of LMS-Google Classroom which can be seen in Figure 1.

![Figure 1. Initial Display of LMS-Google Classroom](image)

Learning will be conducted using Flip-ProBLEM Based Learning, in which digital-based learning (using LMS-Google Classroom) will be applied interchangeably with face-to-face learning (using the syntax of problem-based learning models). As is well known that Flipped-Classroom is one type of Blended Learning model which combines online learning and face-to-face learning. The incorporation of learning used a problem-based learning model which emphasizes contextual problem-based learning. Based on this, the use of problem-based learning models is effective in improving students' mathematical abilities [28]. Hence, the syntax of learning used Flip-ProBLEM Based Learning can be seen in Table 2 [29].

| Step | Procedure                     | Student Activities                                                                 |
|------|-------------------------------|------------------------------------------------------------------------------------|
| 1    | Orientation to the Problem     | Students understand the details of the issue to be discussed. The problem is taken from teaching materials that have been presented through materials in digital classes (LMS-Google Classroom). |
| 2    | Student Organization          | Students are grouped into several discussion groups to solve the problems presented. Students can also discuss through digital classes (LMS-Google Classroom). |
| 3    | Group Investigation           | Students discuss in groups regularly to understand and criticize the problems presented and what solutions can be taken in solving the problems. |
| 4    | Presenting Troubleshooting    | Student groups will present solutions to problems that have been obtained both directly and through videos uploaded to digital classes (LMS-Google Classroom). |
| 5    | Analysis and Evaluation       | Students and teachers jointly analyze the results of the presentation of problem-solving and criticize the results until later to evaluate and draw conclusions. |

Judging from table 2 above, learning will take place alternately between digital-based learning and face-to-face learning. Flipped Classroom not only presents learning that is a combination of online learning and face-to-face learning in class but also provides real experiences to students hence students can experience a learning environment that encourages students' mathematical critical thinking abilities. Besides, students' motivation and curiosity in criticizing mathematical problems can be improved by using a combination of digital and face-to-face learning such as Flipped-Classroom [17,30].
2. Method
This study used quasi-experimental research with pre-test post-test control group design. This study had two sample groups, namely the experimental group (groups of students who are taught using Flip-Problem Based Learning based on LMS-Google Classroom) and the control group (groups of students who are taught using Problem-Based Learning). This research was conducted on students in the age group of 15-17 years, namely groups of students who are in the first level of high school. The research lasted for 8 weeks with 4 hours per week used for online-based learning, that is using LMS-Google Classroom, and 4 hours per week was used for face-to-face learning using problem-based learning (for experimental classes), whereas the control class was conducted 4 hours per week for face-to-face learning using problem-based learning. Learning begins with giving a pre-test as many as five essay-based questions related to statistical material. The end of learning by giving a final test (post-test) of five questions based on essay also related to statistical material.

Data testing on the research results was conducted using a prerequisite test, that is the data homogeneity test using Levenes' Test and the data normality test using the Kolmogorov Smirnov Test. After the prerequisite tests are conducted, the research data were then analyzed using hypothesis testing. Hypothesis testing used the Independent Sample T-Test with the assistance of STATCAL Software.

3. Result and Discussion
Mathematical critical thinking ability data of high school students taught by Flip-Problem Based Learning based on LMS-Google Classroom had an average value (both pre-test and post-test) higher than the data of mathematical critical thinking ability of students taught by Problem-Based Learning. Data table comparing the value of students' mathematical critical thinking skills contained in the two learning groups can be seen in Table 3.

Table 3. Syntax of flip-problem based learning model

| Learning Group                  | N  | Min | Max | Mean  | Standard Deviation |
|--------------------------------|----|-----|-----|-------|--------------------|
| Pre-Test of Experimental class | 30 | 52  | 65  | 59.47 | 3.848              |
| Post-Test of Experimental class| 30 | 72  | 88  | 79.93 | 4.242              |
| Pre-Test of Control class      | 30 | 40  | 63  | 53.13 | 6.157              |
| Post-Test Control class        | 30 | 65  | 82  | 74.17 | 4.907              |

Comparison value of the students' mathematical critical thinking skills based on learning groups can also be seen in the figure 2.

Figure 2. Boxplot graph of comparison value on students' critical thinking ability based on learning
In determining whether there was an increase in students' mathematical critical thinking skills or there wasn't, a normalized gain (NGain) calculation was performed in both learning groups [31]. The NGain scores in the two learning groups can be seen in the figure 3.

![Figure 3](image)

**Figure 3.** Comparison graph of ngain average value in students' critical thinking ability based on learning groups

Based on Figure 3 above, it is seen that the average value of NGain in the experimental class is higher than the average value of N-Gain in the control class (0.51 > 0.44). The next step is to calculate the test for normality and homogeneity of research data. Based on the Kolmogorov-Smirnov Test in each learning group, the results obtained were 0.787 for the experimental group and 0.919 for the control group. Based on these results, it can be concluded that the two learning groups have normally distributed data because the P-value of each learning group is greater than the significant level value, namely 0.787 > 0.05 and 0.919 > 0.05. While the Levene's Test results in the two learning groups obtained results of 0.056 and these results also indicate that the data in both learning groups are homogeneous, this is because the P-value is greater than the significant level value (0.056 > 0.05). Based on the results of data normality and data homogeneity testing, which showed the results that the research data are normally distributed and homogeneous, then hypothesis testing can be done using the Independent Sample T-Test. The results of hypothesis testing using the Independent Sample T-Test using the STATCAL Software can be seen in Table 4.

| Variable    | df | Statistic of T | P-Value |
|-------------|----|----------------|---------|
| Total of N-Gain | 58 | 2.471          | 0.016   |

Based on Figure 4 above, the results were obtained that the value of \( P_{value} = 0.016 \) with the value of \( Statistic \; of \; T = 2.471 \) and the value of \( df = 58 \). Hypothesis testing results showed that the value of \( P_{value} < Sig. \; Value \) (0.016 < 0.05) and the value of \( Statistic \; of \; T > Table \; of \; T \) (2.471 > 2.0017) in which the Table of T (0.05; 60) = 2.0017. Referring to the results obtained, it can be concluded that there is an increase in students' mathematical critical thinking skills taught by using Flip-Problem Based Learning based on LMS-Google Classroom. Increasing in students' mathematical critical thinking skills occur due to the participation of student-centered learning and stimulate students' reasoning power to understand mathematical problems more complex. Problem-based learning provides a major role for students to be able to investigate problems in finding solutions to the problems given. The conducted investigations provide space for students to be able to criticize the extent to which the problem can be overcome and what are the solutions that can be applied as a way to solve the problem.
The collaboration which occurs between students and the teacher's role as a facilitator has a considerable effect on the learning process of students in the classroom [32]. The teacher is as a facilitator in providing scaffolding on which students rely on critical problem-solving processes. Furthermore, the existence of LMS-Google Classroom also cannot be ignored, this provides a new experience for students to understand teaching material independently. The digital-based learning process using Flipped-Classroom based on LMS-Google Classroom makes students more critical in filtering teaching material, and group discussion activities between students are increasingly awakened. Students can understand that the existence of technology makes it easy for them to continue to access teaching material wherever and whenever [33,34].

Learning using Flipped-Classroom creates a flexible learning environment by providing active learning activities and allows students to be able to learn individually and in groups in a responsible manner [35]. Learning using this type enables students to acquire new skills and cause significant changes in students' learning habits. Similar results were also shown in previous studies which stated that there were significant changes in students' learning abilities after implementing digital-based Flipped-Classroom learning [36–39]. This increase in ability also affects the ability of other students, one of which is the ability to think critically which makes it easy for students to understand teaching material hence it can be applied in solving problems around them. The new experience of students in using LMS-Google Classroom makes students more active and enthusiastic to explore one of the Learning Management Systems (LMS) and conduct various interactions and activities independently but still monitored by the teacher. The ease of learning Flip-Problem Based Learning based on LMS-Google Classroom is not only felt by students, but also felt by teachers. Teachers also enjoy new experiences in teaching using digital-based learning. Teachers' skills can be honed and improved in line with the demands of the development of 4.0-based education which places digital-based learning into one of today's learning choices [40,41].

4. Conclusion
Based on the research results above, it can be concluded that mathematics learning using Flip-Problem Based Learning based on LMS-Google Classroom has a significant effect in increasing students' mathematical critical thinking abilities. In addition to mathematical critical thinking skills, students also gain new experiences in participating in digital-based learning. Students also understand better the role of collaboration and joint investigation in solving complex mathematical problems. Students are also increasingly critical in understanding the problems presented and really preparing themselves in preparing plans when carrying out the problem-solving process to draw conclusions. The advantages of digital learning using Flip-Problem Based Learning based on LMS-Google Classroom also have an indirect effect on the teacher who serves as a learning facilitator. A collaboration between online-based learning (using LMS-Google Classroom) and face-to-face learning (using problem-based learning models) has proven to be one of the digital learning solutions that are easily applied in the learning process of mathematics. However, it needs to be marked that although the learning used is digital-based (Flip-Problem Based Learning based on LMS-Google Classroom), the teacher's role is still important. Teachers still have a major role in building student motivation, so as a facilitator to students hence they can understand better the teaching material through strengthening scaffolding.

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