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Abstract. *Encouraging critical thinking is one of the goals in 21st-century education that many education systems want to achieve through schools. However, the results of the research show that education at school is not the main factor in developing this kind of higher-order thinking skills. In today's digital era, where the use of technology in learning, such as Virtual Learning Environments (VLE), when designed with appropriate pedagogical settings such as an emphasis on discourse activities, has enormous potential to make students more actively involved in learning. Although several VLEs for learning mathematics have been developed, the emphasis on discourse as a basis for interventions to develop students' critical thinking skills has not received special attention. Therefore, this study specifically aims to produce a mathematical discourse-based VLE for junior high school mathematics learning and determine its effectiveness on students' ability in thinking critically.*

Keywords: critical thinking; mathematical discourse; virtual learning environment; junior high school

Introduction

The promotion of critical thinking education is one of the main goals of education in the 21st century. However, research findings show that the development of critical thinking skills is not seen as a direct product of the process of providing education in schools [1]. This is because schools rarely teach critical thinking skills explicitly [2], even though teaching these skills explicitly is one of the determining factors in improving students' higher-order thinking skills [3,4]. Critical thinking skills can simply be interpreted as thinking skills that focus on making a decision to believe in something and what action to take next regarding that belief [5]. These skills can be taught explicitly through mathematics learning [6].

In the process of learning mathematics at school, it is not uncommon to find students who only trust the problem-solving process demonstrated by their teacher. It is also not uncommon to find students who mechanically imitate the problem-solving process presented in textbooks. The same phenomenon happened at SMP Muhammadiyah 01 Medan where students generally could

not explain why their solutions were appropriate or not. In addition, the results of the Program for International Student Assessment (PISA) for Indonesian junior high school students in 2018 were quite alarming where Indonesia was ranked 72 out of 77 participating countries of the Organization for Economic Cooperation and Development (OECD) with 379 points below the average and 489 for mathematics competence [7]. This condition needs serious attention.

The learning intervention strategy is a determining factor in the development of student's critical thinking skills [8,9]. Interventions dominated by the teacher's role where students listen more, which does not activate them to ask questions, are the main cause of students' low critical thinking skills [10]. In fact, the development of higher-order thinking skills requires stimulation that creates active interaction between students. This stimulation can be done in the form of discussions and questions and answers about open issues [11]. Active interaction between students can also be carried out through discourse-based learning interventions [12] which are proven to have a significant positive influence on the development of student's critical thinking skills [13]. Thus, explicitly integrating discourse-based intervention strategies into learning in schools needs to be a major concern in developing students' critical thinking skills.

The rapid development of technology is in line with the increasing use of technology in learning, such as Virtual Learning Environments (VLE). If designed in the right pedagogical setting, VLE can be a tool to stimulate students to interact more actively [14] because it provides students with an effective way to learn new skills [15] and gain new knowledge and experiences [16]. An important aspect of creating such learning is the role and participation of teachers and students in virtual classrooms. However, very little literature is devoted to the role of discourse-based VLE in supporting the development of critical thinking, and thus further investigation is warranted.

Several studies have shown that VLE is able to facilitate student discourse [17,18]. This is because this device enables meaningful, contextual, and authentic situations to emerge, and ensures the availability of learning resources for students. Although several VLEs for learning mathematics have been developed (such as [19] and [20]), the emphasis on discourse as a basis for interventions to develop students' critical thinking skills has not received special attention. Therefore, this study specifically aims to produce a mathematical discourse-based VLE for junior high school mathematics learning and determine its effectiveness on critical thinking skills.

Methodology

This research develops a mathematical discourse-based VLE that will be used to support students' critical thinking skills. The research was conducted at SMP Muhammadiyah 01 Medan, a private junior high school in Medan City, in the 2021/2022 academic year. The development process is carried out in four stages, namely analysis, design, development, implementation, and evaluation. Each stage involves two educational experts and two practitioners as resource persons in the Focus Group Discussions. To determine its effectiveness on students' critical thinking skills, the developed VLE was applied to second grade students. Only students who volunteered and had obtained the consent of their parents were involved. The students were matched based on their grade point average in mathematics class, pre-test scores for the critical thinking test, and personal information.

The researchers created a personal information form to see if there were any significant differences in the sociodemographic traits across the groups. In this study, the test previously developed by Firdaus *et al*. [8] was used to collect data on students' critical thinking skills. The

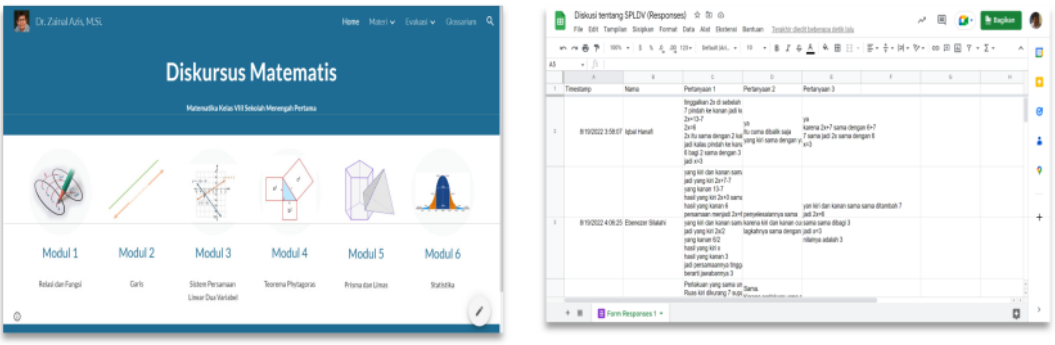
test is translated and written into Indonesian. After going through the examination of linguists, the test was applied to 30 students who were not included in the participants. In the analysis carried out for reliability, the Cronbach Alpha value was found to be 0.73. There were four assessment criteria for student answers to each question in the critical thinking test. If a student writes a complete answer based on the results of his thinking and in accordance with the indicators of critical thinking skills, then the student is given a value of 3 (good). If a student expresses his thoughts incompletely according to the expected critical thinking components, then he gets points 2 (medium). If a student expresses his thoughts in a way that is not in accordance with the expected critical thinking components, then he is given 1 point (enough). If a student does not express his thoughts for each component and standard of critical thinking, then he gets 0 points (bad). Thus, the minimum score is 0 and the maximum score of the test is 51.

The design of this investigation was quasi-experimental with pre-and post-test control groups. Participants were randomly divided into two groups by cluster: the experimental group (n=31) and the control group (n=31). For 16 weeks, the experimental group received 3 hours of discourse-based VLE instruction in geometry every week. The current curriculum was used in the control group.

For the data derived from personal information, frequency and percentage values were computed in the data analysis, and an χ^2 analysis was performed. After the average and standard deviation of students' mathematics scores in the previous semester were calculated, the difference between the mean scores of the sample groups was tested using the Kruskal-Wallis H test. Based on an examination of the pre-test results, the scores obtained by the two groups were normally distributed so t-test analysis was used to assess whether there was a difference between the two groups in terms of pre-test scores. Next, calculations were made of the average of the pre-and post-test scores, standard deviation, post-test adjusted mean, and standard error to perform a covariance analysis of the post-test scores that had been adjusted to the pre-test results. The tests were carried out on the assumptions of ANCOVA.

Results and discussion

After going through each stage in the ADDIE model, discourse-based VLE can be seen in Figure 1 and can be accessed at https://sites.google.com/umsu.ac.id/mathematicaldiscourse.



(a) (b)

Figure 1. The developed discourse-based VLE

Table 1 shows values of the mean and standard deviation of the groups' pre-test and post-

test scores. The corrected mean post-test scores and standard deviation values calculated for covariance analysis are also shown in the table.

Table 1. The values of mean and standard deviation of the groups' pre-test and post-test scores and the values of corrected mean and standard deviation post-test scores.

Groups	N		Corrected Post-test Scores			
			x	SD	Corrected x	SH
Experiment	31	Pre-test	23.25	6.54		
		Post-test	36.01	5.02	36.01	0.70
Control	31	Pre-test	23.47	5.75		
		Post-test	28.32	3.67	28.32	0.70

The average corrected post-test score for the experimental group was found to be 36.01 and 28.32 for the control group, according to the results shown in Table 1. The outcomes of the 2×1 ANCOVA, which was carried out to ascertain whether there was a significant difference between the groups, are shown in Table 2, with the post-test scores adjusted for the pre-test scores.

Table 2. Results of the ANCOVA with Pre-test Score Correction for the Groups.

Source of Variants	Sum of Squares	SD	Mean of Squares	F	Partial	
					p	η^2
Control Group (Pre-test)	294.483	1	294.483	19.447	0.00	0.247
Main Grouping Effect	1006.071	1	1006.071	66.355	0.00	0.528
Error	895.432	59	15.189			
Total	2200.000	61				

There was a statistically significant difference between the groups, as shown in Table 2 ($F(1,59) = 66.355$; $p = 0.00$). This finding implies that the groups' various instructional approaches each had a different impact on the students' mathematical critical thinking. In this study, η^2 was used to gauge the impact's size on students' overall test scores. When assessing the magnitude of the effect, we divided the results into three categories: small effects if the amplitudes less than 0.01, medium effects if the amplitudes between 0.06 and 0.14, and strong effects if the amplitudes greater than 0.14 [9]. As a result, it is clear that the experimental group's strategy has a significant impact ($\eta^2 = 0.528$) on the teaching of critical thinking skills. In this situation, it can be said that 52.8% of the change in the dependent variable is contributed by the intervention strategy with the VLE used, depending on the magnitude of the effect. In conclusion, it was found that the experimental group's educational program had a greater impact on students' mathematical critical thinking skills than the standard curriculum.

Conclusion

This study applies discourse-based VLE as an intervention strategy to both sample groups in a pre-test and post-test quasi-experimental design to investigate its effect on students' critical thinking skills through mathematics lessons. Based on the results of the covariance analysis, there was a statistically significant difference between the two sample groups where the learning outcomes of

the experimental group were higher than the control group. It can be seen that the discourse-based VLE intervention strategy has a positive impact on student's critical thinking skills.

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