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ENCOURAGEMENT OF ACTIVE LEARNING STRATEGIES IN MATHEMATICS COURSES AS AN EFFORT TO IMPROVE STUDENTS' CRITICAL THINKING SKILLS

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ABSTRACT
The current study aims to implement active learning strategies in mathematics courses as an effort to improve students' critical thinking (CT) skills. The randomized pretest-posttest control design was employed to evaluate the efficacy of the active learning strategy intervention, as opposed to expository teaching. The CT skills measured before and after the intervention in each group included indicators: analysis skills (AS), inference skills (IS), evaluation skills (ES), and decision-making skills (DMS). Essay test instruments were developed, validated, and employed to measure CT. Learning interventions with active and expository learning strategies have been analyzed and compared based on indicator (CTi) and individual (CTs) parameters. The results of the study show the advantages of active learning strategies when compared to expository teaching in terms of improving students' CT skills on all CTi indicators. Accompanying the results on CTi, test results based on CTs parameters lead to active learning strategy interventions in mathematics courses that have a significant impact on improving students' CT skills. The information obtained from the results of the current study can provide benefits in the future development of students' CT skills, and has broad implications for many future literature and studies.
Keywords: active learning strategies, mathematics courses, critical thinking skills, expository teaching

INTRODUCTION

The ability to think is one of the assets that students must have as a provision in dealing with the development of science and technology in the present and the future. In addition, the ability to think is also a means to achieve educational goals, namely that students are able to solve high-level problems (Okolie et al., 2021). A person's ability to be successful in life is determined, among other things, by his thinking ability, especially in solving the life problems he faces (Leest & Wolbers, 2021). Many educational psychologists believe that good thinking can and should be developed in universities. Good thinking is meant to create students as independent and critical thinkers (Jiang et al., 2022).

Currently, it is important for students to become independent thinkers in line with the increasing types of jobs in the future that require skilled workers who have the ability to think critically. So far, students' thinking skills have not been fully acquired so that they cannot function optimally in today's society. A report states that learning high-level cognition helps students to become independent learners and train their critical thinking skills (Suhirman et al., 2020). Innovative teaching conduct is suspected to be a driving force for students' critical thinking (Bilad et al., 2022). Even teaching that integrates real-life contexts can provide positive stimulation for students to think critically (Fitriani et al., 2022). Another study proves that an innovative and integrative learning tool can be a learning tool that can position students to become good critical thinkers (Verawati et al., 2022).

On a research scale, existing findings have revealed how critical thinking can be enhanced in learning routines using several different learning approaches (Abrami et al., 2008;

Prayogi et al., 2018b; Prayogi & Asy'ari, 2013; Prayogi & Muhali, 2015; Verawati et al., 2022). It's just that what hasn't been disclosed is related to the active learning that students do to support their critical thinking. Positive perceptions about active learning and adequate teacher understanding of critical thinking are ways in building and fostering students' critical thinking (Alazzi, 2008; Lombardi et al., 2022). This is the most fundamental problem, because it is impossible for us to be able to switch to discourse on increasing students' critical thinking while the existing data or conditions do not clearly describe how active learning is built to support critical thinking.

It should be remembered that the key role of a teacher is to foster students' critical thinking, so that exploration of active learning in an effort to train critical thinking needs to be uncovered (Lombardi et al., 2022). Efforts to train critical thinking in a broader scope usually refer to the use of methods, strategies, approaches and even the models employed. The implication in the learning process is how the method used can trigger active participation among students, teacher and student participation in forming knowledge, making meaning, seeking clarity, being critical, and providing justification for the learning process itself (Arends, 2012). One interesting innovation that accompanies changes in how the paradigm built in learning can trigger active student participation is innovative and constructive learning (Hajhosseini et al., 2016). This is since traditional teaching is considered a failure and not innovative. Active and interactive teaching routes were found to have a positive impact on increasing students' critical thinking dispositions (Hajhosseini et al., 2016). Finally, aspects of routine teaching that are implemented in class need to be further identified, so that they become important bridges and information on the continuation of studies related to the right combination of methods in honing students' critical thinking. Previous studies (for example, Lombardi et al., 2022) paid attention to effective critical thinking teaching methods as guidelines in conducting learning. In the method or model applied, systematic procedures will be illustrated and the organization of learning experiences to achieve learning goals.

Active learning strategies in mathematics lectures are related to interactive presentation styles that are developed in group work and discussions, presentation of solutions voluntarily by groups, student involvement in exploration, involvement and continuous motivation (Lugosi & Uribe, 2022). Its application in teaching calculus has a positive impact on improving student learning outcomes and their graduation rates (Lugosi & Uribe, 2022). Another study recommends restructuring mathematics learning at universities to lead to active learning to support better mathematics learning outcomes (Gruber et al., 2021). An active learning strategy is absolutely necessary, even if the routine of learning mathematics uses technology, where an active learning strategy actually optimizes the activity or process of learning mathematics and improves the performance of student learning outcomes (Webb, 2022). In a broader scope, currently active learning strategies have become departmental development projects in several institutions to achieve success in teaching university mathematics (Kerrigan & Prendergast, 2022).

The current study aims to intervene in active learning strategies in mathematics courses as an effort to improve students' critical thinking skills. The information obtained from the results of the current study can provide benefits in the development of students' critical thinking in the future, and has broad implications for a lot of literature and studies in the future.

METHOD

The randomized pretest-posttest control design (Fraenkel et al., 2012) was employed to evaluate the efficacy of active learning strategies in mathematics courses to improve students' critical thinking skills. The design is as follows.

Experimental group	R	O_1	Exp. Intervention	O_2
Control group	R	O_1	Con. Intervention	O_2

The experimental and control groups were formed from the results of randomization. The experimental group's intervention in learning mathematics was an active learning strategy, while the control group's intervention was using traditional (expository) learning methods. Observations were made before and after the intervention as pretest and posttest respectively. Each intervention is taught in mathematics lectures in the learning outcomes of "determining the solution of problems related to Calculus of one variable real function"

The intervention group as the research sample were those who were taking calculus courses at the Faculty of Science and Engineering, Mandalika University of Education. The number of samples was fifty four which were equally divided into two intervention groups (experimental and control). Demographically, the study sample was between 18 and 20 years old, and gender was relatively balanced between male and female. Ethically, permission to conduct research is issued by the Dean of the Faculty of Science and Engineering.

Critical thinking skills that were measured before and after the intervention in each group included indicators: analysis skills (AS), inference skills (IS), evaluation skills (ES), and decision-making skills (DMS). Essay test instruments were developed, validated, and employed to measure students' critical thinking skills. The test instrument validation results indicated its validity to be employed as a good measuring tool in this study. CT skills are measured based on indicator parameters (CTi) and individuals (CTs). The measured CTi category and score intervals were: very critical ($CTi > 3.21$); critical ($2.40 < CTi \leq 3.21$); quite critical ($1.60 < CTi \leq 2.40$); less critical ($0.80 < CTi \leq 1.60$); and not critical ($CTi \leq 0.80$). While the CTs category and score intervals measured were: very critical ($CTs > 25.60$); critical ($19.20 < CTs \leq 25.60$); quite critical ($12.80 < CTs \leq 19.20$); less critical ($6.41 < CTs \leq 12.80$); and not critical ($CTs \leq 6.41$).

Descriptive analysis of CT data refers to the criteria of CTi and CTs, complemented by an n-gain analysis from Hake (Hake, 1999). The CTi and CTs criteria are broken down into five criteria (very critical to not critical), while the n-gain (CT score increase) is broken down into three criteria (low, medium, and high). Furthermore, statistical analysis (difference test between sample groups) was carried out to determine differences in the increase in critical thinking skills scores in the two intervention groups ($p < .05$). This was preceded by the Shapiro Wilk normality test ($p > .05$). The conclusion of the test results leads to the results of active learning strategy interventions in mathematics courses on improving students' critical thinking skills, and differences in students' critical thinking scores and the control intervention group (as a comparison).

RESULTS AND DISCUSSION

Studies have been conducted that intervene in active learning strategies in mathematics courses as an effort to improve students' critical thinking skills. The summary of the results of the descriptive analysis of critical thinking skills from the two learning intervention groups is presented in Table 1. This is based on the indicator parameters (CTi) on: analysis skills (AS), inference skills (IS), evaluation skills (ES), and decision-making skills (DMS).

Table 1. Results of CTi measurements in two types of interventions

	Indicator	**Pretest**	**Posttest**	**n-gain**
Exp. Intervention	AS	0.94	3.02	0.68
	IS	0.98	3.15	0.72
	ES	1.00	3.11	0.70
	DMS	0.85	3.09	0.71
	$\bar{x}$ CTi	*0.94*	*3.09*	*0.70*
Con. Intervention	**Indicator**	**Pretest**	**posttest**	**n-gain**
	AS	1.09	1.35	0.09
	IS	1.02	1.41	0.13
	ES	1.04	1.37	0.11
	DMS	1.07	1.28	0.07
	$\bar{x}$ CTi	*1.06*	*1.35*	*0.10*

Table 1 shows the results of CTi measurements in the two types of interventions in the different groups. For the experimental group intervention (active learning strategy), the highest increase was found in the inference skills (IS) indicator with n-gain = 0.72 (high criteria), followed by the decision-making skills (DMS) indicator with n-gain = 0.71 (high criteria), evaluation skill (ES) indicator with n-gain = 0.70 (moderate criteria), and finally analysis skills (AS) indicator with n-gain = 0.68 (moderate criteria). The average increase in n-gain for the experimental intervention is 0.70 with moderate criteria.

Evaluation based on the results from the pretest to the posttest showed an increase in the CTi score, from not critical (0.94) to critical (3.09). When compared with the control group intervention (expository teaching), the increase in score (n-gain) on all CTi indicators is low. Their average CTi score was 1.06 in the pretest, and 1.35 in the posttest. They progress from non-critical to less critical. The smallest n-gain score in the experimental group is analytical skills (AS), while in the control group is decision-making skills (DMS). The distribution of CTi scores in the two intervention groups is explained in Figure 1.

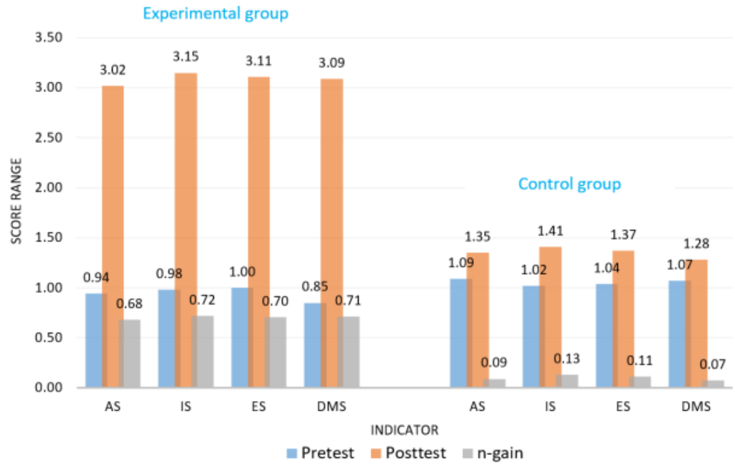

Figure 1. Results of CTi measurements in the two intervention groups

Figure 1 confirms the results of the analysis (based on the CTi parameters) that active learning strategy interventions in mathematics courses are better at improving students' critical thinking skills when compared to traditional (expository) teaching methods. The very wide gap between the two (two different interventions) can be seen in the pretest, posttest, and n-gain scores respectively. Furthermore, the achievement of individual critical thinking scores (CTs) is presented in Figure 2.

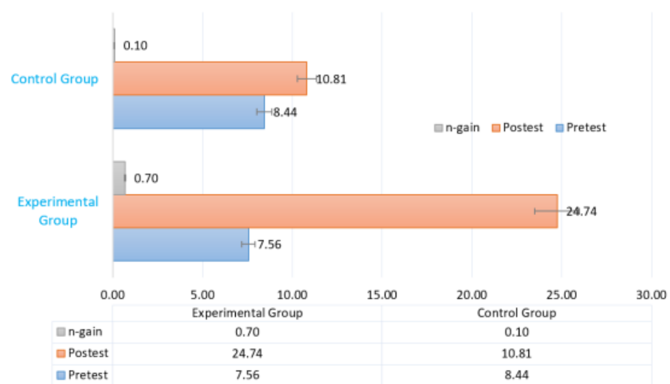

Figure 2. Results of CTs measurements in the two intervention groups

The performance of individual CT (CTs) indicates that active learning strategy interventions in mathematics courses are better at improving students' critical thinking skills when compared to traditional (expository) teaching methods. In the experimental group, based on the CTs parameters on the pretest-posttest, students' CT skills increased from less critical to critical. Obviously this is not the same as the results shown in the control group taught in traditional ways, they are still in the less critical category. The results of the descriptive analysis of the n-gain analysis in both groups are presented in Table 2.

Table 2. The results of the descriptive analysis of the n-gain analysis

Group			Statistic	Std. Error
Exp. Intervention	Mean		.7022	.01679
	95% Confidence Interval for Mean	Lower Bound	.6677	
		Upper Bound	.7367	
	5% Trimmed Mean		.7012	
	Median		.6800	
	Variance		.008	
	Std. Deviation		.08724	
	Minimum		.58	
	Maximum		.84	
Con. Intervention	Mean		.0963	.01486
	95% Confidence Interval for Mean	Lower Bound	.0657	
		Upper Bound	.1268	
	5% Trimmed Mean		.0963	
	Median		.0900	
	Variance		.006	
	Std. Deviation		.07722	
	Minimum		-.05	
	Maximum		.23	

Furthermore, a statistical analysis was carried out on the difference in score increase (n-gain) between the intervention groups, this was preceded by a normality test. The results of the normality test showed that the experimental intervention group had sig (0.024) <0.05, and was normally distributed. Meanwhile, the control intervention group had sig (0.396) > 0.05, and was not normally distributed. One of the test groups is not normally distributed, so the different test uses non-parametric parameters (Mann Whitney test). The result is sig (0.000) <0.05, meaning that there is a significant difference in the increase in student CT (n-gain parameter) between the two treatment groups. The conclusion of the test results leads to an active learning strategy intervention in mathematics courses that has a significant impact on improving students' critical thinking skills. The cumulative overall results show that there is a difference in student CT between the two intervention groups, and it is clear that the active learning strategy intervention is better than teaching with traditional or expository approaches.

The encouragement of active learning strategies in mathematics lectures is related to interactive presentation styles that are built in group work and discussions, presentation of solutions voluntarily by groups, student involvement in exploration, involvement and continuous motivation (Lugosi & Uribe, 2022). Interactive presentation styles have been researched before and have had significant interaction and beneficial pedagogical effects on students in learning (Wang et al., 2021). Attractive discussions in groups can build positive interactions, especially those related to the material students are discussing. In an active learning strategy, when students have interactive discussions, they simultaneously build arguments, and several interpretations may emerge from the results of these interactive discussions. The connection with critical thinking is the process of interpretation and building arguments, which are ways for someone to build their critical thinking (Romero Ariza et al., 2021). Collaborative and discussion practices are strongly encouraged in learning mathematics at all levels of education. To support student growth as superior mathematics learners, student involvement in argumentation is one way (Cardetti & LeMay, 2019).

Student involvement in exploration is the most important element of an active learning strategy. Student involvement in exploration, especially to solve mathematical problems, is a way of supporting the development of their critical thinking skills (Evendi et al., 2022). In an extended learning rhythm, exploratory processes related to inquiry, and previous studies have evaluated the success of exploratory methods in inquiry to improve students' critical thinking performance (Prayogi et al., 2018a; Verawati et al., 2019, 2022; Wahyudi et al., 2018, 2019). In every learning condition, the aspects needed are student involvement in learning and learning motivation, however, everyone needs a reason to stay in the learning they are living. People who are engaged in teaching mathematics may be curious why student involvement is an important aspect of learning mathematics. Student engagement is a supporting aspect of active learning. They are able to contribute to improving math skills for students, increasing retention, and can increase the success rate in learning mathematics (Stanberry, 2018). In addition to involvement, the motivational aspect is a supporter of student involvement in learning mathematics. Motivation to learn mathematics has an impact on increasing interest in learning, mastery of material content, and self-efficacy during the learning process (Daher, 2022). In a more detailed study, students who are motivated or motivated in learning have better performance in three contexts (interest in learning, self-efficacy, mastery of content), when compared to regular teaching with traditional learning methods. In line with the findings of the current study, that the performance of students' critical thinking skills is better in active learning when compared to expository teaching.

Currently, in line with the increasingly urgent needs related to adequate pedagogy in every learning rhythm that is built, active learning strategies can be a solution to develop students' critical thinking skills. The proof of its success is in learning mathematics as the results of the current study. It is acknowledged that this strategy does have its peculiarities, the main thing is that it requires strict learning control, especially in building student interaction and motivation. However, if we think about the results to be achieved especially for the purpose of training critical thinking, then an active learning strategy is the best solution.

CONCLUSION

Studies intervening active learning strategies in mathematics courses have been carried out. The goal is to improve students' critical thinking skills. Learning interventions with active and expository learning strategies have been analyzed and compared based on indicator (CTi) and individual (CTs) parameters. The results of the study show the advantages of active learning strategies when compared to expository teaching in terms of improving students' critical thinking skills on all CTi criteria (analysis skills - AS, inference skills - IS, evaluation skills - ES, and decision-making skills - DMS). Accompanying the results on CTi, test results based on CTs parameters lead to active learning strategy interventions in mathematics courses that have a significant impact on improving students' critical thinking skills. The cumulative overall results show that there are differences in student CT between the two intervention groups, and it is very clear that the active learning strategy intervention is better than teaching with traditional or expository approaches.

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This study used two different interventions with one variable being measured, perhaps some contexts biased the results achieved. This is part of the shortfall in the current research. Apart from that, the researcher would like to thank the parties involved and make a positive contribution to this study.

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P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

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Article Error You may need to remove this article.

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PAGE 4

Article Error You may need to use an article before this word. Consider using the article **the**.

Frag. This sentence may be a fragment or may have incorrect punctuation. Proofread the sentence to be sure that it has correct punctuation and that it has an independent clause with a complete subject and predicate.

Article Error You may need to remove this article.

Prep. You may be using the wrong preposition.

Article Error You may need to remove this article.

Article Error You may need to use an article before this word. Consider using the article **a**.

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PAGE 5

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Missing "," You may need to place a comma after this word.

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PAGE 8

Article Error You may need to use an article before this word.

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