

Connected Mathematics Project in Vocational School: A Teaching Quality that Improves student's Mathematical Reasoning and Resilience

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Abstract

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Mathematical reasoning and resilience are essential skills that students need to master in the process of learning mathematics. Both of these skills can be cultivated through instructional models that stimulate students to construct their own knowledge by connecting learning to the real world. One instructional model characterized by these aspects is the Connected Mathematics Project (CMP). Consequently, the purpose of this study is to analyze the effectiveness of the CMP instructional model in enhancing mathematical reasoning and resilience abilities. This research employs a quantitative approach utilizing a quasi-experimental design, specifically the nonequivalent posttest-only control group design. The study was conducted in one vocational high school in Majalengka. Sample selection was carried out using the cluster random sampling technique, resulting in a total of 18 students in the experimental group and 18 students in the control group. The research instruments comprised a mathematical reasoning ability test consisting of three open-ended test items and a mathematical resilience questionnaire. The findings of this study indicate that: (1) students' mathematical reasoning abilities in the CMP instructional model are higher compared to those in conventional instruction; (2) the average percentage of students' resilience attitudes in the CMP instructional model is higher than those in conventional instruction; and (3) CMP instruction is effective in improving both mathematical reasoning and resilience abilities among vocational high school students.

INTRODUCTION

Mathematics education in vocational schools plays a crucial role in preparing students for the workforce and developing their skill sets. FitzSimons (2014) emphasizes that mathematics education in vocational schools not only equips students for employment but also supports their progression to

higher education. Additionally, Lacroix (2014) highlights that mathematics education in vocational schools prepares students to work effectively and tackle complex challenges in professional settings.

In the context of learning mathematics in vocational schools, students are required to engage in reasoning. The significance of reasoning in mathematics education has been widely recognized (Barnes, 2018), as it forms the basis for constructing and justifying mathematical arguments. Ball and Bass (2003) emphasize that reasoning is a fundamental skill upon which children's mathematical utilization relies. Reasoning stands as a pivotal competency within mathematical subjects, particularly in vocational schools. Consequently, mathematical reasoning within this context should be a focal point for mathematics educators. Mathematical reasoning involves activities such as formulating hypotheses, evaluating mathematical arguments, discerning patterns and relationships, and employing problem-solving strategies (Kramarski & Mevarech, 2003; Stein et al., 1996).

Nonetheless, mastering mathematical reasoning presents challenges for students. It is common for them to encounter obstacles and alter their thought processes while pursuing reasoned inquiries (Mason et al., 2010). This can lead to emotions like frustration or perplexity (Goldin, 2000). Some studies indicate that the reasoning abilities of vocational school students have not reached the desired level, implying that their reasoning skills remain underdeveloped. Additionally, negative attitudes toward mathematics have been observed among students. Such negative attitudes should not be disregarded by educators. Yusof & Tall (2008) reveal that negative attitudes often emerge when students struggle with problem-solving or exams. If this situation persists, it can affect students' academic achievements. Therefore, it is crucial for students studying mathematics to possess mathematical resilience.

Mathematical resilience refers to the quality that enables some students to approach mathematics with confidence, perseverance, and a willingness to engage in discussion, reflection, and research (Lee & Ward-Penny, 2022). Mathematical resilience has been defined as a set of attitudes that theory suggests are predictive of a positive response to studying mathematics despite negative experiences (Kooken et al., 2013). Although psychological resilience has been researched extensively (Luthar et al., 2000; Luthar, 2007) the study of resilience in an academic setting and specifically resilience in the study of mathematics represents a relatively new approach (Johnston-Wilder & Lee, 2010; Rivera & Waxman, 2011; Yeager & Dweck, 2012). Research (e.g., Kooken et al., 2016; Lee & Johnston-Wilder, 2013; Williams, 2014) has identified four aspects on which mathematical resilience is based: valuing mathematics, understanding how to work through challenges, adopting a growth mindset, and being part of a supportive learning community.

Hence, to ensure mathematics is embraced by students, innovative instructional approaches are needed, such as implementing teaching models that enhance students' reasoning skills. One such alternative is the Connected Mathematics Project (CMP) model.

Connected Mathematics Project is an instructional model that emphasizes tasks related to mathematics (Cain, 2002; Damaryanti et al., 2017). The primary goal of CMP is to aid students and educators in developing mathematical knowledge, comprehension, skills, and an appreciation for the interconnectedness of mathematical concepts and their relationships with other disciplines (Wahyuningsih, 2017). The CMP model necessitates educators to think diversely about problem-centered teaching. This approach opens up mathematics classrooms to exploration, conjecture, reasoning, and communication.

Previous research has demonstrated the success of the Connected Mathematics Project in mathematics education. Purnamasari (2013) found that the adaptive reasoning abilities of students improved more significantly in the CMP model compared to conventional methods. Similarly, Wafirah

(2019) discovered that a high-quality CMP-based Quantum Learning approach had a positive impact on students' mathematical reasoning abilities. However, this study aims to explore the effects of the Connected Mathematics Project on both mathematical reasoning and mathematical resilience. The research seeks to determine whether the CMP instructional model is suitable for mathematics education by analyzing its effectiveness in enhancing both reasoning skills and resilience.

Consequently, educators can gain insight into students' levels of mathematical reasoning and implement appropriate strategies for those with lower reasoning abilities. Given this context, this study aims to analyze the effectiveness of the CMP instructional model in enhancing mathematical reasoning and resilience abilities

METHODS

This research is a quantitative study conducted using experimental and quasi-experimental methods. According to Sugiyono (2013), the objective of quantitative methods is to establish relationships between variables, test theories, and generalize findings. Quasi-experimental design is chosen when it is not feasible to control all relevant variables in a true experimental setting, aiming to obtain estimates of information comparable to that in actual experiments (Suryabrata, 2013). The chosen quasi-experimental design is the nonequivalent posttest-only control group design.

The study was conducted in one vocational high school in Majalengka. The sample selection utilized cluster random sampling, leading to the selection of Class XII A as the experimental group, receiving the CMP instructional treatment, and Class XII B as the control group, which received no specific treatment (conventional instruction with a scientific approach). The research instruments comprise two types: test instruments, consisting of open-ended test questions to measure mathematical reasoning abilities, and non-test instruments, consisting of a questionnaire to measure the level of mathematical resilience. The test instrument consists of three open-ended questions with indicators related to proposing logical answers based on reasoning, performing mathematical manipulations, evaluating the validity of an argument, identifying patterns or characteristics of mathematical phenomena, making generalizations, and drawing conclusions from statements. The non-test instrument, the questionnaire, is composed of 12 statements, with six positive and six negative statements.

The data analysis technique employed in this research is non-parametric statistical analysis due to the small sample size. The specific non-parametric statistical test used is the Mann Whitney U test. The Mann Whitney U test is a non-parametric statistical test used to compare differences between two independent samples. This non-parametric test is commonly employed when the assumptions of the independent samples t-test are not met (Lestari & Yudhanegara, 2018). Furthermore, the effectiveness of the CMP instructional model on mathematical reasoning abilities is determined based on the Cohen's effect size measure (1992). Meanwhile, the influence of the CMP model on mathematical resilience will be analyzed descriptively based on the percentage of student attitudes indicating their level of mathematical resilience.

RESULTS AND DISCUSSION

This study aims to analyze the effectiveness of the CMP instructional model in enhancing mathematical reasoning and mathematical resilience. The data for this research were collected through a mathematical reasoning ability test and a mathematical resilience questionnaire. The results of the mathematical reasoning ability test for both the experimental and control groups are presented in Table 1.

Based on Table 1, in the control group, for indicator 1, a total of 4 students did not provide any answers or provided incorrect answers. No student provided partial conjectural answers, no student was able to present near-complete and accurate conjectural answers, 14 students were able to provide complete and accurate conjectural answers, and no student scored 4. For indicator 2, 16 students did not provide any answers or provided incorrect answers, 1 student only offered partial conjectural answers, no student was able to present near-complete and accurate conjectural answers, no student was able to provide complete and accurate conjectural answers, and 1 student scored 4. For indicator 3, 6 students did not provide any answers or provided incorrect answers, 5 students only provided partial conjectural answers, 2 students were able to present near-complete and accurate conjectural answers, 5 students were able to provide complete and accurate conjectural answers, and no student scored 4.

Table 1. Mathematical Reasoning Ability Test Results in the Experiment Class and Control Class

No	Mathematical Reasoning Ability Indicator	Score	Experiment Class	Control Class
1	Submitting alleged answers based on logical reasons	0	0	4
		1	0	0
		2	0	0
		3	18	14
		4	0	0
2	Provide alternatives to an argument	0	0	16
		1	0	1
		2	0	0
		3	8	0
		4	10	1
3	Perform mathematical manipulation	0	0	6
		1	0	5
		2	0	2
		3	18	5
		4	0	0

Meanwhile, in the experimental group, for indicator 1, no student failed to provide any answers or provided incorrect answers, no student offered partial conjectural answers, no student was able to present near-complete and accurate conjectural answers, 18 students were able to provide complete and accurate conjectural answers, and no student scored 4. For indicator 2, no student failed to provide any answers or provided incorrect answers, no student only offered partial conjectural answers, 8 students were able to present near-complete and accurate conjectural answers, and 10 students were able to provide complete and accurate conjectural answers. For indicator 3, no student failed to provide any answers or provided incorrect answers, no student only offered partial conjectural answers, 18 students were able to present near-complete and accurate conjectural answers, 5 students were able to provide complete and accurate conjectural answers, and no student scored 4. The distribution of answers for the mathematical reasoning ability test for the experimental and control groups is presented in Table 1.

The data from the mathematical reasoning ability test were analyzed using the Mann Whitney U test to determine if students' mathematical reasoning abilities with the CMP instructional model were higher than those with conventional instruction. The results of the Mann-Whitney test at the 5% significance level, using the assistance of XLSTAT, are presented in Table 2.

Table 2. Reasoning Ability Test Results With the Help of XLSTAT Software ($\alpha=0.05$)

Mathematical reasoning abilities	
Mann-Whitney U	274
Expected value	162
Variance (U)	962,871
P-value. (one-tailed)	0,000
Alpha	0,05

From Table 2, the statistical calculation using XLSTAT yielded a p-value that is smaller than the significance level alpha. Thus, the null hypothesis (H_0) is rejected. Consequently, it can be concluded that at a 95% confidence interval, the mathematical reasoning abilities of students in the CMP instructional model are significantly higher than those in the conventional instruction. Furthermore, the calculated effect size using Cohen's d is 0.8. Utilizing Sawilowsky's criteria (2003) as presented in Table 2, it can be inferred that the CMP instructional model is effective in enhancing mathematical reasoning abilities.

Table 3. Mathematical Resilience in Experimental Class

No.	Math Resilience Indicator	Negative Answer				Positive Answer			
		SS	S	TS	STS	STS	TS	S	SS
1	Willingness to learn and master mathematics.	0	9	8	1	0	6	8	4
2	Awareness of the importance of learning and mastering mathematics	0	9	8	1	1	7	9	1
3	Self-confidence in being able to learn and master mathematics	0	15	3	0	1	7	8	2
4	Awareness that mathematical knowledge is useful when learning subjects other than mathematics	1	4	11	2	0	16	1	0
5	Ability to overcome difficulties in learning and mastering mathematics	6	6	6	0	4	12	0	2
6	Awareness of the significant role of mathematical knowledge in the future	1	9	7	1	0	10	7	1
		8	52	43	5	6	58	33	10

Moving on to the level of mathematical resilience, data was obtained from the questionnaire using response options "Strongly Agree" (SA), "Agree" (A), "Disagree" (DA), and "Strongly Disagree" (SDA). Based on the data analysis of the questionnaire responses from the experimental group, it is revealed that within the cognitive resilience dimension, for the indicator "Willingness to learn and master mathematics," in negative questions, none chose "SA," 9 chose "A," 8 chose "DA," and 1 chose "SDA." In positive questions, none chose "SDA," 6 chose "DA," 8 chose "A," and 4 chose "SA." Then, for the indicator "Awareness of the importance of learning and mastering mathematics," in negative

questions, none chose "SA," 9 chose "A," 8 chose "DA," and 1 chose "SDA." In positive questions, 1 chose "SDA," 7 chose "DA," 9 chose "A," and 1 chose "SA."

Regarding the indicator "Self-confidence in being able to learn and master mathematics," in negative questions, none chose "SA," 15 chose "A," 3 chose "DA," and none chose "SDA." In positive questions, 1 chose "SDA," 7 chose "DA," 8 chose "A," and 2 chose "SA." Then, for the indicator "Awareness that mathematical knowledge is useful when learning subjects other than mathematics," in negative questions, 1 chose "SA," 4 chose "A," 11 chose "DA," and 2 chose "SDA." In positive questions, none chose "SDA," 16 chose "DA," 1 chose "A," and none chose "SA."

For the indicator "Ability to overcome difficulties in learning and mastering mathematics," in negative questions, 6 chose "SA," 6 chose "A," 6 chose "DA," and none chose "SDA." In positive questions, 4 chose "SDA," 12 chose "DA," none chose "A," and 2 chose "SA." Furthermore, in the indicator "Awareness of the significant role of mathematical knowledge in the future," in negative questions, 1 chose "SA," 9 chose "A," 7 chose "D," and 1 chose "SDA." In positive questions, none chose "SDA," 10 chose "DA," 7 chose "A," and 1 chose "SA." The distribution of responses from the experimental group students towards the mathematical resilience questionnaire is presented in Table 3.

On the other hand, within the cognitive resilience dimension for the control group, it is observed that for the indicator "Willingness to learn and master mathematics," in negative questions, none chose "SA," 9 chose "A," 9 chose "DA," and none chose "SDA." In positive questions, 1 chose "SDA," 4 chose "DA," 10 chose "A," and 3 chose "SA." For the indicator "Awareness of the importance of learning and mastering mathematics," in negative questions, none chose "SA," 7 chose "A," 9 chose "DA," and 2 chose "SDA." In positive questions, none chose "SDA," 4 chose "DA," 7 chose "A," and 7 chose "SA."

Table 3. Mathematical Resilience in Control Class

No.	Math Resilience Indicator	Negative Answer				Positive Answer			
		SS	S	TS	STS	STS	TS	S	SS
1	Willingness to learn and master mathematics.	0	9	9	0	1	4	10	3
2	Awareness of the importance of learning and mastering mathematics	0	7	9	2	0	4	7	7
3	Self-confidence in being able to learn and master mathematics	0	13	5	0	0	3	12	3
4	Awareness that mathematical knowledge is useful when learning subjects other than mathematics	0	3	10	5	0	5	12	1
5	Ability to overcome difficulties in learning and mastering mathematics	1	6	8	3	0	10	5	3
6	Awareness of the significant role of mathematical knowledge in the future	1	12	5	0	0	9	9	0
		2	50	46	10	1	35	55	17

Regarding the indicator "Self-confidence in being able to learn and master mathematics," in negative questions, none chose "SA," 13 chose "A," 5 chose "DA," and none chose "SDA." In positive questions, none chose "SDA," 3 chose "DA," 12 chose "A," and 3 chose "SA." For the indicator "Awareness that mathematical knowledge is useful when learning subjects other than mathematics," in

negative questions, none chose "SA," 3 chose "A," 10 chose "DA," and 5 chose "SDA." In positive questions, none chose "SDA," 5 chose "DA," 12 chose "A," and 1 chose "SA." For the indicator "Ability to overcome difficulties in learning and mastering mathematics," in negative questions, 1 chose "SA," 6 chose "A," 8 chose "DA," and 3 chose "SDA." In positive questions, none chose "SDA," 10 chose "DA," 5 chose "A," and 3 chose "SA."

Furthermore, in the indicator "Awareness of the significant role of mathematical knowledge in the future," in negative questions, 1 chose "SA," 12 chose "A," 5 chose "DA," and 3 chose "SDA." In positive questions, none chose "SDA," 9 chose "DA," 9 chose "A," and none chose "SA." The distribution of responses from the control group students towards the mathematical resilience questionnaire is presented in Table 4.

Overall, the description of the average percentage of mathematical resilience attitudes between the experimental and control group students is presented in Figure 1.

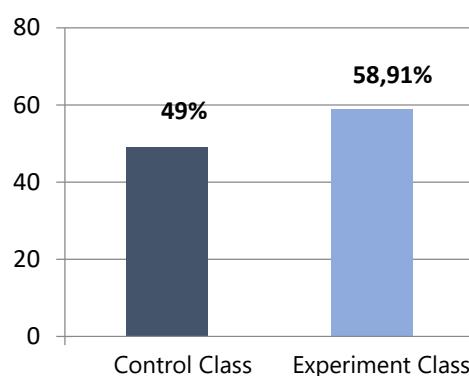


Figure 1. Average Percentage of Students' Math Resilience Attitude

Based on Figure 1, it can be concluded that the average percentage of mathematical resilience levels for the experimental group students is higher than the average percentage of mathematical resilience levels for the control group students. The results indicate that the mathematical resilience of students in the CMP group is better compared to the conventional group.

From the conducted data analysis, this research demonstrates that the Connected Mathematics Project (CMP) is effective in enhancing students' mathematical reasoning abilities. This finding is in line with the study conducted by Lidwina & Citroresmi (2021), which states that the CMP has an impact on middle school students' mathematical reasoning abilities. CMP emphasizes the integration of mathematics-related tasks (Cain, 2002; Damaryanti et al., 2017). CMP teaches mathematics in a way that is more connected to the real world and aims to develop a deep understanding of mathematical concepts, rather than merely teaching formulas and procedures. The study by Ketterlin-Geller & Chard (2011) supports the idea that when students have a strong conceptual foundation through connections, their effective learning of mathematical concepts will improve their interest and performance. This concept is further supported by Greer (2008) and Sciarra (2010), who suggest that students may struggle with understanding mathematical concepts due to a lack of connection between mathematical topics and real-life problems.

CMP assists students in developing knowledge, understanding, and mathematical skills, as well as awareness and appreciation of the interrelatedness of different parts of mathematics and other disciplines (Wahyuningsih, 2017). CMP emphasizes the comprehension of mathematical concepts rather than rote memorization of formulas (Rohendi & Dulpaja, 2013). This approach aids students in developing stronger mathematical reasoning, as they understand how and why a concept or formula

works. This approach makes mathematics meaningful to students by establishing connections between various mathematical topics and problems in other disciplines (Ginsburg & Amit, 2008; Winheller et al., 2013). CMP also promotes the interconnection between different mathematical concepts (Harahap, 2020), helping students see relationships between various mathematical topics, thus enhancing their ability to formulate mathematical arguments. CMP involves students in real problem-solving situations (Andriani et al., 2020), aiding them in developing mathematical reasoning skills by applying learned concepts in various contexts. CMP encourages logical thinking and deductive reasoning (Breyfogle & Lynch, 2010; Sari & Darmanto, 2016). Students are guided to construct mathematical arguments and take logical steps to reach solutions.

Furthermore, this research also demonstrates that the Connected Mathematics Project is effective in enhancing students' mathematical resilience. CMP emphasizes understanding mathematical concepts rather than rote memorization of formulas (Rohendi & Dulpaja, 2013). A deep understanding of mathematical concepts provides a strong foundation for students to face various types of mathematical problems. Students with mathematical resilience possess a growth belief related to their abilities in this area. They do not perceive mathematics as exclusionary, as something that other people understand but that they do not; even when the student herself is experiencing difficulties, she retains her confidence in an eventual, successful outcome. The learner is aware of resources to assist her, and even if these are not to hand, she retains confidence in their existence and utility. The learner retains a positive affective stance in relation to mathematics (Goodall, J., & Johnston-Wilder, 2015). CMP often engages students in problem-solving related to real-life scenarios (Cain, 2002; Damaryanti et al., 2017), helping them develop the ability to apply mathematical concepts in different situations, making them better prepared to tackle mathematical challenges. CMP also encourages students to approach solutions from different perspectives and use diverse approaches. This can help develop confidence and perseverance in tackling challenging problems. Students with mathematical resilience possess a growth belief related to their abilities in this area. They do not perceive mathematics as exclusionary, as something that other people understand but that they do not; even when the student herself is experiencing difficulties, she retains her confidence in an eventual, successful outcome. The learner is aware of resources to assist her, and even if these are not to hand, she retains confidence in their existence and utility. The learner retains a positive affective stance in relation to mathematics.

CONCLUSION

Drawing insights from the test data analysis, it can be deduced that the mathematical reasoning skills of students using the CMP learning method exhibit a notable increase in comparison to those employing the conventional learning method, with a 95% confidence level. Concurrently, an examination of the questionnaire data reveals that, on the whole, the mean percentage of mathematical resilience among CMP group students surpasses that of their counterparts in the conventional learning group. In essence, this implies that the CMP model demonstrates a relative effectiveness in enhancing both students' mathematical reasoning and resilience capacities.

However, the effectiveness of CMP in improving students' mathematical reasoning and resilience abilities might be influenced by various factors, including the quality of curriculum implementation, students' needs and characteristics, as well as the support provided by teachers and the learning environment. Empirical studies conducted in real-world settings could provide further insights into the actual impact of CMP on enhancing students' mathematical reasoning.

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