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Abstract

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Keywords: Critical Thinking, Marzano's New Taxonomy, Intervention, Pre-Test-Post Test

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Title

Marzano's New Taxonomy: Implications for Developing Critical Thinking Skills

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Abstract

This quasi-experimental study investigates the effects of an instructional intervention based on Marzano's New Taxonomy on critical thinking development in seventh-grade students. Using the Solomon Four-Group Design, 180 students were randomly selected from a government girls' high school in Haripur, Pakistan. The intervention emphasized Marzano's self-system and metacognitive system to foster cognitive engagement and analytical reasoning. Over three months, students participated in structured activities aimed at enhancing critical thinking. The Figural Intersection Test, assessing working memory where critical thinking occurs, was used to measure impact. Results indicated significant improvement in students' critical thinking skills, with history and maturation having no notable influence reinforcing internal validity. These findings suggest that the intervention, rather than external factors, led to the observed gains and underscores the broader applicability of Marzano's framework in enhancing critical thinking within educational context.

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Contents

Introduction

Among the key objectives of education in the new millennium is the development of critical thinking (CT) abilities (Winch, 2006; Laxman, 2010; Lau, 2011; Kharbach, 2012; Al-Osaimi, 2013; Khan, 2019; Haber, 2020). It is regarded as a skill that will be heavily relied upon by future generations to make sensible decisions and effectively fulfill the expectations of the job (Aizikovitsh-Udi & Cheng, 2015). It includes concepts like independent learning, self-regulatory thinking, a habit of inquiry, innovation and creation, problem-solving, and reasoning. Critical thinking forms the foundation of Pakistan's National Education Policy (2009) as well as the curricula for mathematics, English, and general science.

However, students in Pakistan often absorb information and replicate it as accurately as possible (Khan, 2019). Critical thinking involves a structured and thoughtful approach to interpreting, applying, analyzing, synthesizing, and assessing information derived from observation, experience, reflection, reasoning, or communication. It serves as a foundation for forming beliefs and making decisions (National Council for Excellence in Critical Thinking, 2014). Despite numerous efforts, students in even the most developed countries, such as the USA, lack adequate high school or college CT abilities (Trilling & Fadel, 2009). Teaching methods are blamed by Kivunja (2015), Pelajaran (2013), and Bermingham (2015) for failing to foster students' capacity for critical thought.

According to Flavell's (1979) initial proposal of the metacognitive theory, metacognition is reflecting on one's thought process and its results. According to Schraw and Dennison (1994), the two core elements of metacognition are knowledge of cognition (KC) and regulation of cognition (RC). According to Mevarech and Kramarski (2014), metacognition is the capacity of an individual to monitor his cognitive activities. The framework guiding this study's design is the New Taxonomy of Educational Objectives, introduced by Marzano and Kendall (2007). This taxonomy is unusual because it recognizes the importance of self-system and metacognition as key cognitive processes in learning. According to the literature, developing CT abilities involves both a disposition for and a willingness to think critically (Lau, 2011; Al-Osaimi, 2013; Khan, 2019). According to Marzano's New Taxonomy (MNT), the self-system is divided into three sublevels: evaluating importance, efficacy, and emotional response. These factors concern the learner's personality and capacity for critical thought.

According to Lau (2011), who examines the nature of CT, prior knowledge is necessary but does not guarantee CT; this cognitive action results from both capacity and willingness. Lau (2011) highlights several characteristics linked to critical thinking, including openness to new ideas, impartiality, adaptability, a tendency to seek rational justifications, a strong interest in acquiring knowledge, and a willingness to respect and evaluate diverse perspectives. Lau (2011) distinguishes three distinct methods of CT: philosophical, cognitive psychology, and educational approaches. Manan and Mahmood (2015) assert that when someone questions knowledge and assesses its value, they engage in critical thinking. Mitrevski and Zajkov (2011) state that CT is goal-oriented, concentrated, and cohesive. DiYanni (2015) states it is the capacity for productive questioning. Logical thinking is based on the reasoning needed to solve problems (Page & Mukherjee, 2006). According to Bermingham (2015), CT has four fundamental components: logic, impartiality, reflective thinking, recognition that power dynamics shape our ideas, and a desire to produce a useful outcome.

Onwumere and Reid (2014) define working memory as an active location for information filtering before storage or release.

For students to be able to address problems, CT is considered a necessary talent (Johnson, 2009; Bermingham, 2015; Zare & Othman, 2015; Kivunja, 2015; Dwijayanti et al., 2020). To create people who can meet the needs of the twenty-first century, CT capabilities are a key component of the 21st-century educational vision (Kivunja, 2015). According to Facione (2011), there are very few situations or locations where it does not have potential benefit. Khan (2019) has highlighted students' capacity to apply CT to assess and utilize pertinent data from the deluge of information. According to Heo and Chun (2018), teaching students to sift through information to find what is relevant, supported by evidence, and logical.

According to Zimmerman (2008), metacognition is an ongoing learning process in which students actively participate, complete preparatory activities, and monitor and assess themselves. Peirce (2003) defines it as a person's capacity to evaluate their current knowledge and predict the information and skills required to complete a task, using that knowledge to solve problems effectively. While contrasting the effects of intrinsic and extrinsic motivation, Shannon (2008) emphasized the importance of metacognitive thinking in enhancing

learners' intrinsic motivation and, consequently, their chances of success. Seeking alternative solutions, understanding issues comprehensively, and tracking progress toward goal achievement are all skills of a meta-cognitively engaged learner (Little, 2009).

Since the infusion strategy requires less work from the instructor to incorporate such abilities into lesson plans, many educators support it (Kong, 2005; Kuhn, 2000; Ennis, 1985).

Bensley and Spero (2014) support using direct infusion because it improves metacognitive abilities and CT. We cannot simply hope that including implicit CT in instruction will enhance students' CT, according to specific arguments (Abrami et al., 2008; Haber, 2020). According to research, the questioning technique successfully forces students to consider, analyze, and evaluate the information before reaching a choice (Brown & Kelley, 1986; Snyder & Snyder, 2008). According to Thompson (2011), asking insightful questions is one of the finest strategies for encouraging higher-order thinking skills.

Integrating Marzano's New Taxonomy of Educational Objectives into educational interventions provides a structured framework for enhancing students' CT skills. CT is essential for seventh-grade students as they transition into more complex subjects and social dynamics, making it crucial for their academic and personal development. Marzano's New Taxonomy emphasizes the cognitive processes involved in learning, promoting a deeper understanding of knowledge through various levels—from retrieval to analysis and knowledge utilization. By implementing an intervention based on this taxonomy, educators can offer targeted strategies encouraging students to analyze, evaluate, and create, enhancing their CT skills (Marzano & Kendall, 2007). When students encounter challenging scenarios, they are encouraged to consider solutions and articulate their thinking, thus enhancing mathematics' inherent ability to stimulate CT (Su et al., 2016; Aizikovitsh & Amit, 2010; Rajendran, 2010). Individuals can effectively manage cognitive processes, particularly during learning (Bermingham, 2015). Numerous scholars have noted that a lack of intentional and explicit integration of self-regulation into pre-, post-, and during-learning processes may impede deep learning (Kramarski & Zoidan, 2008; Kistner et al., 2010). Self-directed learners can utilize relevant data to validate tentative solutions (Gureckis & Markant, 2010). Conducting this study is crucial as it aims to build upon and extend the existing academic discourse concerning the specific impacts of structured interventions on critical thinking in middle school settings. The findings could potentially inform future educational practices, contribute to curriculum design, and ultimately result in better student outcomes in critical thinking, preparing them for the complexities of higher education and real-world challenges.

The investigation proceeded based on the following null hypotheses:

There is no…

H_{01}. statistically meaningful difference between the pre-test and post-test results concerning critical thinking abilities within the experimental group that received a pre-test.

H_{02}. statistically significant variation between the pre-test and post-test scores of the control group in terms of their critical thinking skills.

H_{03}. statistically difference in the post-test performance on the critical thinking assessment between the two experimental groups one that underwent a pre-test and the other that did not.

Theoretical Framework

Facione (2011) states that a critical thinker seeks evidence to support knowledge and possesses an inquisitive mind. Willingham (2007) claims that CT encompasses utility, originality, and self-control. As Al Osaimi (2013) described, the operational form of CT consists of unseen mental processes in working memory, executed by the individual confronting an issue and attempting to devise a workable solution by utilizing their knowledge and experiences. The literature highlights three training approaches for developing higher-order thinking skills (Wakefield & Kirk, 1996; Cotton, 1999; Al-Heela, 2002; Alsorur, 2003; Guttami, 2005; Al-Karaki, 2007). Various thinking programs present critical thinking as content

delivered through a direct teaching method (Kong, 2005). Al-Degether (2009) critiques the direct teaching strategy that addresses critical thinking skills in isolation, as he views them as specific to each subject. Willingham (2007) argues that teaching CT skills on particular subjects favors domain-specific instruction over direct instruction. Conversely, Ennis (1989) contends that domain-specific instruction fails to prepare students to apply these skills in real-world situations.

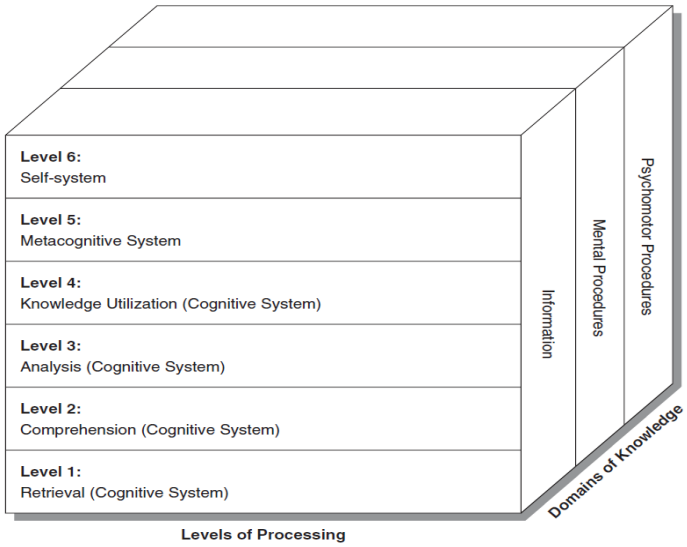
Strong evidence shows a student's learning and metacognitive skills are positively associated (Gulikers et al., 2006; Cilla Choresh et al., 2009; Perry et al., 2017). Schoenfeld et al. (2014) introduced a similar concept, mathematical agency, which refers to the ability and inclination for mathematical reasoning that involves making connections between ideas, providing justifications, and generating one's knowledge. When math teachers adopt metacognitive teaching strategies, research indicates that students' mathematical literacy improves (Mevarech & Fan, 2018). However, practical information is scarce that can empower teachers to utilize metacognitive activities in the classroom (Ericson, 2015). According to Veenman and Spaans (2005), the absence of explicitly incorporating these activities in teacher education programs may contribute to this issue.

Marzano's New Taxonomy

Separating various knowledge levels from the cognitive processes that act on certain kinds of knowledge is the primary divergence of Marzano's New Taxonomy-MNT (Marzano & Kendall, 2007). The self-system is the first cognitive reaction to a new task, which begins by simultaneously assessing the activity's significance, motivational potential, and learner efficacy level (Irvine, 2017). These factors work closely together to produce devotion and motivation (Marzano & Kendall, 2007).

Figure 1

Two-Dimensional Taxonomy of Learning (Marzano & Kendall, 2007)

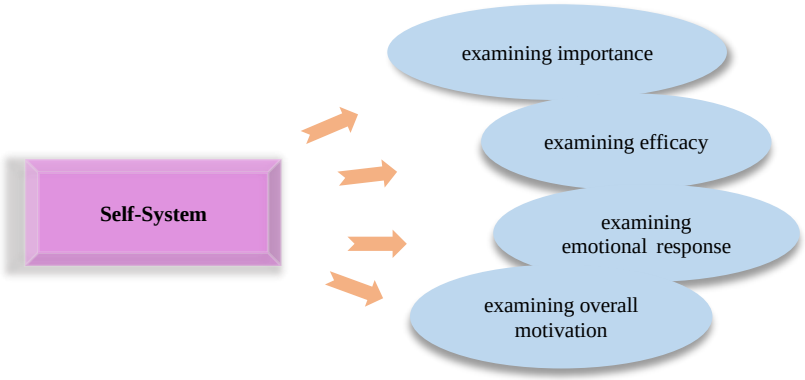


Self-system (Level 06)

In contrast to Bloom's taxonomy (1956) which views the self-system as a starting point for deciding whether or not to engage with a new learning assignment, Irvine (2017) refers to it as a bottom-up approach. The self-system produces four types of thinking: "Evaluating significance, effectiveness, emotional reaction, and motivation in general."

Figure 2

Components of Self-System



Examining the importance

Evidence in the literature shows that psychologists agree on the significance of learning tasks based on satisfying basic needs and achieving personal goals (Marzano & Kendall, 2007).

Examining the efficacy

The ability to achieve one's goals is known as efficacy. Marzano and Kendall (2007) highlight the importance of an individual's efficacy beliefs in the learning process.

Examining Emotional Response

According to Marzano's Taxonomy, the moment a learner is presented with a job to complete, he begins to assess its emotional value.

The metacognition system (level 05) allows one to observe, evaluate, and modify all cognitive actions (Brown, 1984; Flavell, 1976). These characteristics give the cognitive system complete control over its operations (Sternberg, 1986a, 1986b).

Dispositional in nature are the final two functions (Brown, 1984; Flavell, 1976).

According to the National Education Policy (2017), "addressing the instructional needs of a child, which involve both educational contents (knowledge, skills, values, and attitude) along with academic tools (literacy, numeracy, problem-solving, and oral expression)" (p.10) is one of the goals. While acknowledging the importance of issue-solving, McCormick et al. (2015) assert that the critical thinking abilities employed in the problem-solving strategy include problem analysis, prior knowledge utilization, and solution creation. The "power of reasoning, validating and communicating thoughts" is something that mathematics gives students (NCM, 2006, p.1). Standard five of the curricula, which focuses on reasoning and logical thinking, is the area most obviously devoted to developing critical thinking. By employing appropriate reasoning and supporting conclusions with evidence, this criterion seeks "to enable the learner to promote his/her mathematical thinking" (p. 7).

According to the National Professional Standards for Teachers (NPST) in Pakistan (2009, p. 2), it is widely accepted that "standards provide the yardstick to gauge and ensure the quality of prospective teachers." The NPSTP's subsection analysis reveals that the disposition component across all standards focuses on helping aspiring teachers develop the mental habits necessary to support their students' advanced cognitive abilities.

Methodology

The quasi-experimental Solomon Four Group design (SFG) has been employed in this experimental study. Pretest-posttest and posttest-only control group designs are combined in the SFG design, which is a real experimental design. This design overcomes nearly all validity risks by combining an intervention without a pretest with a posttest that does not include

either the pretest or the intervention. This strengthens the study's external validity (Yu, 2018; Flannelly et al., 2018; Maheshwari, 2017). The experiment's internal validity determines how certain we are that the change in the dependent variable that we saw because of treatment was caused by the independent variable (Muijs, 2004; Lodico et al., 2010). Marsden and Torgerson (2012) believe that experimental and quasi-experimental designs provide an opportunity to present trustworthy outcomes for establishing cause-and-effect relationships. Campbell and Lapsey (2021) used Solomon's four-group quasi-experimental design in their study.

Sampling

The sampling method was multistage. The second-largest public sector urban girls' high school in the district of Haripur, Khyber Pakhtunkhwa province of Pakistan, which has 227 pupils enrolled in grade level 7 across five sections, was selected as the example institution for the first phase. It was representative of an urban public school (typical case sampling). Using cluster randomized sampling, four of these five sections of seventh-grade students were randomly allotted to be whichever control or experimental (Lopata et al., 2019; Spybrook et al., 2020). So, 180 students made up the sample. Cluster randomization may help reduce the effect of treatment contamination, according to Radulovic and Stancic (2017). To determine whether respondents have the same position, their accomplishments before the start of the intervention are examined (Bleske-Rechek et al., 2015).

Equating Research Groups

Four study groups were compared based on students' socioeconomic background and academic performance. The baseline data for mathematics achievement was used from the preceding school's annual exam to guarantee the equity of all four groups. These groups were statistically equated using ANCOVA. According to Sirin (2005), a moderate to significant association exists between pupils' academic achievement and social background. Socioeconomic status was also identified by Hiller et al. (2020) as the most important predictor of mathematical achievement. The researcher created a questionnaire for the sample students' socioeconomic survey that enquired about:

1. Parental academic qualification (of both parents)
2. Profession/occupation of both parents
3. Average monthly income of parents
4. Mathematics tutoring at home
5. Availability of Internet facility
6. Opportunity for independent use of the Internet
7. The device used to get connected to the Internet
8. Use of the Internet for learning mathematics
9. Time spent using the Internet for learning mathematics

Mothers of students in all four groups had matriculation-level or lower academic qualifications (A: 90%, B: 94%, C: 80%, D: 96%). Most of the fathers of the pupils in all four groups had academic credentials below matriculation (A: 90%, B: 81%, C: 87%, D: 83%). In all four categories, 90% of the students' mothers were housewives and did not have a job. In all four categories, over 70% of fathers worked as retailers and grocers (A: 73, B: 71%, C: 91%, D: 80%). In almost 80% of the four groups, dads' monthly incomes stay at or below 30,000 PKR. The average household size in Haripur is seven, per the District Haripur 1998 Census Report. According to the United Nations Development Program Annual Report (2020), the poverty line is set at $2 (Pakistani Rupees 337) per person per day, meaning an individual must earn 10,110 Pakistani rupees per month to be above it. For an average household to be over the poverty line, they must earn at least 70000 PKR monthly. Therefore, every student in the sample came from a low-income family.

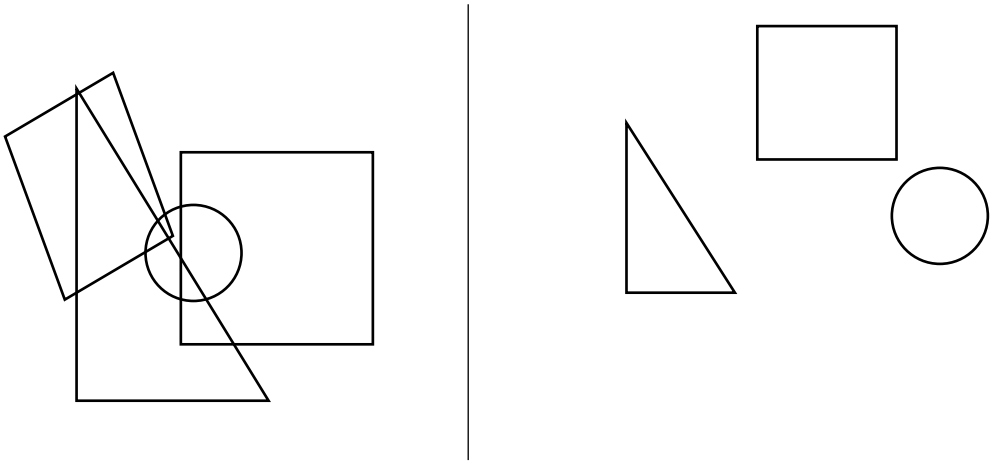
Research Instrument

Al-Osaimi (2013) utilized Pascual-Leone and Smith (1969) to create the Figural Intersection Test to evaluate working memory capacity (WMC). In this cognitive domain, critical thinking examines how Saudi Arabian seventh-grade pupils have developed their critical thinking skills in science. This test features several variations, each helpful in determining WMC (Reid, 2003).

The twenty-item test has been employed for this investigation. While test-retest reliability must be established, literature provides evidence of the test's internal consistency (Reid, 2006). The test-taker must identify the overlapped area of each relevant figure, which is displayed separately in the right half of the paper. All figures are shown in the left half of the page, creating a single common area for all. To check if the test-taker remains focused on the relevant figures, one or more irrelevant figures may be placed on the left-hand side alongside those on the right. Below is an example:

Figure 3

Solomon Four Group Design Data Analysis



Data Collection

Data collection took place in two phases: the pre-test (PRT) and the post-test (POT). Both tests were administered in a controlled hall environment, ensuring that all students experienced a standardized setting. Individual observation was maintained throughout to prevent cheating or idea sharing. The pre-tests on critical thinking (CT) ability were administered to two study groups: the experimental group (EG) and the control group (CG). After the PRT phase, two sets of scores were recorded. Following this, all groups—EG and CG—took the post-test on critical thinking skills. Four sets of scores were gathered after the POT phase. Both phases of the test were conducted between 9:30 and 11:30 a.m.

Data Analysis

To investigate the cause-and-effect relationship between the intervention and students' CT skills, several comparisons were conducted:

To determine baseline equivalency for assessing initial differences, the pre-test scores of the EG and the CG (with PRT) were compared. To ascertain the effects of the intervention and evaluate its effect on CT abilities, the experimental group's PRT and POT scores were compared. In order to assess natural progression, a comparable comparison was then done for the control group (using a PRT) to examine changes in CT skills over time in the absence of the intervention. The effectiveness of the intervention was then assessed by comparing the post-test results of the experimental and control groups (both with pre-test results).

Comparisons were made to take into consideration any unrelated factors that might have an impact on the test of critical thinking abilities. To ascertain whether the pre-test had an impact on the results, the POT scores of two EG—one with a PRT and the other without—were compared. To determine whether there were any differences, the POT results of the two control groups—one with a pre-test and the other without—were examined. To observe the direct influence of the intervention without prior testing effects, the POT scores of the EG and CG (both without a PRT) were compared. To find any naturally occurring differences, the PRT scores of the CG (with a pre-test) and POT scores (without a pre-test) were compared.

Internal Validity of Experimental Research

There are both internal (pitfalls in research design and process) and external (studies occurring concurrently with interventions) factors that can interfere with the accuracy of the results in an experiment (Shadish et al., 2002; McLeary et al., 2017). Some recommendations that are frequently made in the literature to guarantee the internal validity of the experimental study include carefully selecting respondents, carefully piloting study instruments, and closely adhering to study protocols (Shadish et al., 2002; Lodico et al., 2010; Gass et al., 2021; Gass & Mackey, 2017).

The study utilized several statistical techniques to evaluate the intervention's impact. A t-test compared means between independent groups, while a paired t-test assessed pre- and post-test differences within groups. Cohen's d measured effect size to determine practical significance, and descriptive analysis summarised socio-economic data. The assumptions of the t-test—continuous data, adequate sample size (N > 30), and normal distribution—were satisfied. Levene's test examined variance equality to guide the interpretation of the t-test (Muijs, 2004). Although statistical significance ($p < 0.05$) indicates reliability (Nakagawa & Cuthill, 2007), effect size (Glass, 1976; Maher et al., 2017) illustrates the real-world importance of the findings. Cohen's d is a widely used measure of effect size, where 1.00 indicates a strong effect (Muijs, 2004, p.135). This study integrates statistical significance with effect size analysis to ensure a well-rounded interpretation of the intervention's effectiveness.

Findings

The following tables depict the results of the study:

Table 1

Comparison of PRT and POT scores for the CT skills test of the EG (with pre-test)

Test	N	Mean	SD	SE Mean	Correlation (p)	Paired Difference			t (p)
						M	SD	SEM	
Post	45	14.62	2.68	.39	.048	-4.84	4.08	.61	-7.95 (0.000)
Pre	45	9.78	3.21	.48	0.67				

Table 1 presents the results of the dependent sample t-test for the EG that participated in both the PRT and POT of the CT skills assessment. The pre-test scores (EWPT) had a mean of 9.09 (SD = 3.16, SE Mean = 0.48), whereas the post-test scores (EWPTPOT) showed an increase, with a mean of 10.66 (SD = 3.48, SE Mean = 0.53). The t-test yielded a t-value of -2.87, with a p-value of 0.019, below the 0.05 threshold for statistical significance. Additionally, the correlation coefficient between the pre-test and post-test scores was 0.211, with a p-value of 0.67, indicating a weak association between the two scores. Despite this, the significant difference in means suggests that the experimental group performed better in the post-test, demonstrating improved critical thinking skills following the intervention. Based on these findings, the following null hypothesis was overruled.

H_{01}. There is no statistically meaningful difference between the pre-test and post-test results concerning

critical thinking abilities within the experimental group that received a pre-test.

Table 2

Comparison of PRT and POT scores of the CT skills test for the CG (with pre-test)

Test	N	Mean	SD	SE Mean	Correlation (p)	Paired Difference			t (p)
						M	SD	SEM	
Post	42	10.66	3.49	.538	.211	-1.571	4.185	.646	-2.875 (0.019)
Pre	42	9.09	3.16	.487	0.67				

Table 2 presents the results of the dependent sample t-test for the CG that participated in both the PRT and POT of the critical thinking abilities assessment. The pre-test scores (CWPT) had a mean of 9.78 (SD = 3.21, SE Mean = 0.47), while the post-test scores (CWPOT) showed a substantial increase, with a mean of 14.62 (SD = 2.68, SE Mean = 0.39). The t-test produced a t-value of -7.95, with a p-value of 0.000, indicating a highly significant difference between the two scores. These results propose that the control group improved CT skills in the POT. Based on this statistically significant difference, the following null hypothesis was rejected.

H_{02}. There is no statistically significant variation between the pre-test and post-test scores of the control group in terms of their critical thinking skills.

Table 3

Comparison of POT scores of the CT skills test of two EG (one with pre-test and the other without pre-test)

Group	N	Mean	SD Score	SE Mean	t-value	Sig.	Effect Size
EWOPRPOT	42	13.43	1.99	.30	-2.344	.021	0.50
EWPRPOT	45	14.62	2.69	.40			

Table 3 presents the results of an independent sample t-test comparing the POT scores of the EG without a PRT (EWOPRPOT) and the experimental group with a pre-test (EWPRPOT). The mean score for EWOPRPOT was 13.43 (SD = 1.99, SE Mean = 0.30), while the mean score for EWPRPOT was 14.62 (SD = 2.69, SE Mean = 0.40). The t-test yielded a t-value of -2.344, with a p-value of 0.021 below the 0.05 threshold for statistical significance. These results show a statistically significant difference in performance between the two groups at a 95% confidence level, with a moderate effect size of 0.50. Based on this evidence, the following null hypothesis was rejected.

H_{03}. There is no statistically difference in the post-test performance on the critical thinking assessment between the two experimental groups—one that underwent a pre-test and the other that did not.

Discussion

Both experimental groups showed notable improvement in their post-test scores on the critical thinking (CT) assessment. This outcome supports prior research emphasizing the teachability and development of CT skills. For instance, Al Osaimi (2013) conducted a study in Saudi Arabia and confirmed that CT competencies can be evaluated and enhanced among secondary school students using targeted instructional strategies. Similarly, Liang (2016) explored the capacity of students and educators to justify mathematical reasoning—a critical component of CT—and observed that participants in the experimental group demonstrated superior reasoning abilities. In the same vein, Amir (2016), through a quasi-experimental approach, assessed the effects of a problem-solving framework on 21st-

century learning competencies, finding that students in the EG significantly outshined their CG counterparts.

To address potential confounding variables, the Solomon Four-Group (SFG) design was adopted, as it facilitates robust causal inferences by balancing or neutralizing extraneous factors. This method blends two classic experimental frameworks: the pre-test–post-test CG design and the post-test-only CG design (Wiersma & Jurs, 2009).

The results indicated that the pre-test alone did not significantly affect post-test outcomes, as both control groups achieved comparable results in the CT post-assessment. However, a notable interaction effect emerged: the experimental group that undertook a pre-test outperformed the group that did not, implying that the pre-test might have enhanced participants' focus or engagement with the intervention. Overall, the study found no substantial influence of pre-testing, historical effects, or maturation, thereby reinforcing the internal validity of the findings and supporting a causal link between the instructional intervention and the development of CT skills.

In the CT skills test, the EWPRPOT group significantly outperformed the EWOPRPOT group. Since both groups received the same intervention, this difference can be attributed to pre-test interaction. The unique format of the test likely engaged participants more actively, making the pre-test a contributing factor to improved post-test performance. Consequently, while the mathematics achievement results may be generalized to populations not undergoing pre-testing, the results of CT skills may not be generalizable to non-pre-tested populations.

Conclusions & Recommendations

The results point out that the intervention was successful in fostering the development of CT skills, as evidenced by the substantial post-test gains observed in both experimental groups. The comparable POT outcomes among the CGs suggest that the PRT, in isolation, did not have a measurable effect on performance. Interestingly, the EG that underwent the PRT achieved higher POT scores than the group that did not, suggesting a potential interaction effect. This may be attributed to the pre-test heightening participants' cognitive engagement or awareness, thereby enhancing the effect of the instructional intervention. Furthermore, the lack of significant effects from extraneous factors such as historical events, maturation, or the pre-test alone reinforces the validity of the findings and supports a strong causal relationship between the intervention and the observed improvement in CT skills.

Additionally, the superior performance of the EWPRPOT group compared to the EWOPRPOT group, despite identical interventions, further underscores the role of pre-test interaction. Therefore, while mathematics achievement results may be generalizable, the CT skills findings may not extend to populations without pre-testing. Before experimentation, students should be introduced to the Figural Intersection Test and other nonverbal tests that measure CT skills. Repeated exposure to such materials before actual testing may help reduce pre-test sensitization, allowing students to become familiar with the format and structure of these assessments. Lessons designed using MNT of Learning as a teaching framework could be a valuable resource for textbook writers. The intervention model from this study may guide paper setters in formulating assessment tasks that emphasize advanced thinking skills, ensuring alignment with CT objectives in mathematics. Due to COVID-19 restrictions, only 33% of the allocated teaching time was used during this study. Replicating the study under full teaching time conditions is expected to yield even better results, allowing for a more comprehensive assessment of the intervention's effectiveness. Before and during service teacher drill programs should incorporate the proposed intervention into mathematics instruction training. This inclusion could enhance teachers' ability to develop students' CT skills, making the intervention scalable across different educational contexts.

This study involved entirely female learners. Future research should include male and female students to examine potential gender-based variations

in learning outcomes. Replicating this study in rural school settings would help determine if the same intervention is effective for students from diverse socio-economic and educational backgrounds. Long-term research utilizing the lesson plan approach based on MTN of Learning could be conducted across grades six, seven, and eight. This approach would help evaluate whether sustained exposure to the intervention leads to long-term improvements in CT skills.

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