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Making the Invisible Visible: Using Equalities as Metaphors of Critical Thinking and Reading Comprehension

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Critical thinkers and proficient readers use a composite of similar cognitive skills that are challenging to assess and difficult to cultivate. Therefore, students and teachers require an instructional model that demonstrates the acuity involved in these proficiencies. This quasi-experimental study aimed to investigate the impact of Equalities as Metaphors instruction on the critical thinking and reading comprehension achievement of grade 7 students during and after language arts instruction versus traditional teaching methods. A nonrandom sample of 43 grade 7 students from one elementary school in Northern New Jersey participated in the study. Students placed in the intervention group (n = 21) received Equalities as Metaphors instruction. The control group (n = 22) received traditional language arts instruction. The teacher used grade 7 textbooks with supplementary materials for language arts instruction in both groups. Following the pretest-posttest nonrandom control group design, t-test results indicated that language arts instruction affected the critical thinking and reading comprehension achievement of grade 7 students regardless of teaching method (i.e., traditional versus Equalities as Metaphors instruction). However, the intervention group significantly outperformed the control group. The researcher recommended using Equalities as Metaphors instruction on a larger sample throughout an instructional year.

Keywords: critical thinking, reading comprehension, metaphor, mathematical thinking, equalities, Cognitive theory

INTRODUCTION

The United States government enacted several educational initiatives to measure critical thinking and reading comprehension capability to improve student achievement. The initiatives included No Child Left Behind, Race to the Top, and Common Core State Standards legislative acts, demonstrating the United States Governments' desire to provide quality learning and teaching results for the nations' children. Despite the Governments' efforts, these legislative acts failed to improve student learning, teaching, or standardized test scores (James et al., 2016). Leaders in the educational field interested in developing students capable of making judgments about reading content based on presented evidence and reasoning should include the best teaching practices that impart critical thinking (Karademir & Ulucinar, 2017). Cognitive models that help students synthesize related thinking and reading comprehension skills improve student analysis (Zubaidah et al., 2018). Language and mathematics share conceptual commonalities and interchangeable verbiage that increase critical thinking, writing, and reading comprehension (Bosse et al., 2018; Seo, 2009). Traditional thinking holds that mathematics comprises facts, operations, and quantification absent of linguistic themes. However, the ability to make unbiased judgments, which are the hallmarks of critical thinking, joins the skills needed to engage in mathematics and literature (Sriraman, 2004). Students trained to think critically apply skills required to see beneath disparate objects or ideas to uncover the equal value that unites them (Yousefi & Mohammadi, 2016).

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Educational leaders identified critical thinking skills as essential for students to thrive in a knowledge-based economy (Nhat et al., 2018). Critical thinking involved higher-order cognitive processes that included generalizing, evaluating appropriate information to draw reasoned conclusions, comprehending text, and succeeding in the workforce (Forbes, 2018; Siburian et al., 2019). Critical readers exhibited similar essential thinking abilities involved in critical thinking that included synthesizing cognitive elements to achieve comprehension (Cer & Sahin, 2016). Critical thinkers use cognitive skills linked to comprehending text (Mulsem et al., 2017). Mathematical thought promoted critical thinking and increased students' communication ability (Purnomo et al., 2021). Students demonstrated critical thinking and reading comprehension skills by transitioning from language to mathematics in a structured, linear thinking process (Wilkinson, 2015). The cognitive abilities found in language and mathematical thinking aided critical thinking development (Erath et al., 2018). Children engaged in primary and middle school demonstrated the ability to convey arguments involving inductive reasoning and supporting stated claims with evidence through mathematical thinking (Maher & Yankelewitz, 2017).

An essential skill required to train the brain to evaluate information analytically, improve problem-solving, and decision-making involved the ability to think (Prajapati et al., 2017). Educational leaders recognized the need to develop critical thinkers yet remained unfamiliar with effective teaching methods to impart the skill and activities that fostered critical thinking (Webster, 2018). Middle school students struggled to analyze, evaluate, and synthesize information in various forms beyond answering basic level questions, skills required to achieve expected academic and career success (Walters, 2017). Limited research addressed middle school students' critical thinking and reading comprehension struggles and the use of mathematical models as metaphors to improve thinking capacity (Aizikovitsh-Udi et al., 2016; Song, 2019).

The Equalities as Metaphors instructional approach mirrors the notion that reading ability equates to solving a math problem. An author uses words, sentences, and paragraphs to express ideas through parts of speech that provide a roadmap for the critical reader to arrive at a central thesis (Gates, 1956; O'Halloran, 2015; Thorndike, 1917; Wilkinson et al., 2018). Metaphors signify comparison between two distinct entities by demonstrating the first subject has equal value to the second (Scott et al., 2010). Readers used metaphors as a conceptual framework to comprehend complex ideas of equal value and facilitate a new understanding of an old topic (Latterell & Wilson, 2017). Readers used critical thinking and comprehension skills to deconstruct an entire text to fit into a cognitive structure. Students reconstructed essential concepts from the text inside the cognitive structure based on established linguistic standards until the text and cognitive structure are mirror images (Halpern, 2013). Cognitive models provided practical methods for students to analyze, evaluate, and synthesize parts of presented information (Celikoz et al., 2019). Instructional models helped individuals mentally synthesize language and mathematics skills to acquire critical thinking and reading comprehension (Zubaidah et al., 2018).

Mathematical thought supported educational leaders' defined direction toward the expectation of teachers' encouragement of students to provide evidence of the thought process involved in arriving at a particular conclusion (As'ari & Kurniati, 2019). Equalities as Metaphors instruction provided students with the 1 + 1 = 2 models to represent ideas in a text that authors express through linguistic techniques. Students trained to think of language mathematically used iterations of the equality 1 + 1 = 2 as a source domain to acquire critical thinking and reading comprehension, the target domain, described in (Luo, 2018). Research conducted by Wulandari, Rochmad, and Sugianto (2020) revealed that students required critical thinking to navigate the demands of 21st-century technology, yet critical thinking ability remains low among middle school students. The decline of critical thinking and

reading comprehension skills among middle school students challenged educational leadership to seek the most effective educational methods to meet academic standards and the demands of a changing economy (Spichtig et al., 2016). A curriculum void of critical thinking instruction is not compatible with the ideals of promoting quality education and adds to the struggles of middle school students (Song, 2019).

Learning models allow scholars, researchers, and educators with innovative strategies to develop critical thinking and reading comprehension skills impart thinking abilities applicable for academic, business, and personal growth while meeting high stakes testing demands (Scogin et al., 2017). Empowering all learners to reach each educational goal on Bloom's Taxonomy can only be achieved when students engage in learning experiences that foster critical thinking and comprehension (Verawati et al., 2020). Teachers equipped to teach critical thinking effectively prepare students for the challenges of high-stakes testing and social expectations (Sultan et al., 2017).

Research Questions

The purpose of the current study is to answer the following research questions:

RQ1: What statistical impact does language arts instruction have on the combined critical thinking and reading comprehension test scores of grade 7 students regardless of the teaching method (i.e., Equalities as Metaphors instruction or traditional language arts instruction)?

RQ2: To what extent does language arts instruction incorporating Equalities as Metaphors impact the combined critical thinking and reading comprehension achievement of grade 7 students?

RQ3: To what degree does the method of language arts instruction (i.e., Equalities as Metaphors instruction versus traditional language arts instruction) affect the difference between pre-test and post-test combined critical thinking and reading comprehension test scores of grade 7 students?

Research Objective

The objective of this study was to investigate the impact of Equalities as Metaphors instruction on grade 7 students versus traditional language arts instruction.

Closing the Gap

Though Thorndike (1917) equated the reading skills required to understand a text to solving a math problem, a research gap remains in the literature that focuses on the instructional benefits of teaching language, critical thinking, and reading comprehension skills through mathematical ideas. A systematic search of educational literature college online library sources, books, and scholarly journals revealed a plethora of research showing how language acquisition increases mathematical competence and processing skills. Few studies focus on mathematical models designed to offer teachers, students, and educational leaders instructional practices to help perceive, learn, and apply linear theories included in mathematical methods. Mathematical models allow students access to critical thinking and reading skills required to comprehend various expressions of communication. Equalities as Metaphors instruction provides language arts intervention based on mathematical ideas to address this gap.

METHOD

Research Design

This study used a quasi-quantitative research design. The quasi-experimental design matching allowed for a control group that makes generalization possible despite the inability to assign random participants and the lack of accessibility to large populations (Campbell & Stanley, 2015). Forty-three grade 7 students were selected using a pretest-posttest nonrandomized control group technique to

investigate the effect of Equalities as Metaphors instruction on critical thinking and reading comprehension performance.

Sample

The sample for this study was the middle school population at the host elementary school consisting of 120 middle school students. The 120 middle school students included 40 grade 6, 43 grade 7, and 37 grade 8 students. No middle school students enrolled in traditional language arts classes were exempt from potential participation in this study. However, the grade 7 students were the only middle school population who returned the principal's consent forms and became the study's sole focus.

The teacher assigned a convenient sample of grade 7 students from two classrooms to the intervention group (n = 21) and control group (n = 22) at the beginning of the study. Each class contained language arts students who had not received Equalities as Metaphors instruction at any time before this study. The intervention and control group received instruction from the same language arts teacher who received training using Equalities as Metaphors instruction that included integrating the intervention into a traditional language arts classroom. The control and intervention classes were pre-tested with the Partnership for Assessment of Readiness for College and Careers (PARCC) assessment and received a post-test after seven weeks.

Instrumentation

The design of the PARCC assessment was an appropriate instrument for this study. The PARCC assessment requires students to utilize critical thinking and reading comprehension in tandem (New Jersey Department of Education, 2017- 2018). The PARCC assessment presents questions designed to measure high-level reading skills, critical thinking, and analysis to complete an Evidence-Based Selected Response EBSR (PARCC, 2016). In an (EBSR), students only receive full credit when both the reading comprehension and critical thinking parts of the response align. However, students receive partial credit for providing a correct answer to only the reading comprehension part of the response. Students receive no credit for a valid response solely on the critical thinking portion of the (EBSR).

Data Collection

The participant teacher collected student responses to Equality as Metaphors instructional materials daily and held them until the end of the study. The technology person at the host school provided students access to pre-test and post-test PARCC assessments at the beginning and end of the study. With permission from the host building principal, the tech person collected and compiled the results, then presented them for analysis after the study.

Data Analysis

The use of descriptive statistics tested two general statistical assumptions: normality and homogeneity of participating groups' variance: descriptive statistics and further analysis provided data that described each group separately and in total. T-tests compared the mean scores of the intervention and control groups. Results indicated a significant statistical difference between the pre-test and post-test results in favor of the intervention group. The researcher used that statistical difference to determine the effect of Equalities as Metaphors instruction on combined critical thinking and reading comprehension skills. The significance level selected for this quasi-experimental study was .05 as the P-value for rejecting the null hypotheses. The post-test was dependent, and the instructional method was the independent variable (i.e., Equalities as Metaphors instruction vs. traditional language arts instruction.). Cohen's convention for effect size (.08) determined whether Equalities as Metaphors instruction significantly affected critical thinking and reading comprehension skills.

Assumptions of normality for both factors were conducted using a Shapiro -Wilks test (Shapiro & Wilks, 1965). The data indicated normal distribution of pre-test scores (W (21) = .97, p > .05 for intervention group; (W (22) = .98, p > .05 for control group) (see Table 1). Data indicated normal distribution post-test scores for the intervention group (W (21) = .95, p > .05; control group (W (22) = 97, p > .05).

FINDINGS

Analysis of the findings contained in this quasi-quantitative study can be found in the impact Equalities as Metaphors instruction had on the combined critical thinking and reading comprehension performance of grade 7 students.

Table 1
Shapiro – wilks test for normally distributed data

Test	Intervention Group		Control Group	
	W	P	W	P
Pretest	.97	.828	.98	.99
Posttest	.95	.464	.97	.725

Levine's Test of Equality of Variances examined the homogeneity of variance test. The achievement of homogeneity assumes the null hypothesis when the group error variance does not reveal a significant difference (Field, 2009). Data indicated no statistically significant group error variance in the pre-test (F (1,41) = .049, (p> .05) or post-test (F (1,41) = 1.303, (p > .05), which met the standard of equality of variances assumed in the independent sample t-test. (See Table 2).

Table 2
Levine's independent samples t-test for equality of means

Pre-test	F	Sig	T	Df.	Two tails) Sig.	Mean Difference	Std. Error difference	95% Confidence Interval of the Difference	
Equal variances Assumed	.049	.826	.083	41	.934	.47835	5.75035	Lower 11.13	Upper 12.09
Test Equal variances not assumed			.083	40.7	.934	.47835	5.75509	11.14	12.10
Post-test	F	Sig	T	Df.	Two tails) Sig.	Mean Difference	Std. Error difference	95% Confidence Interval of the Difference	
Equal Variances Assumed	1.303	.260	3.14	41	.003	19.995	6.358	Lower 7.15	Upper 32.8
Test Equal Variances Not Assumed			.083	40.7	.934	.47835	5.75509	7.08	32.9

RQ1: What statistical impact does language arts instruction have on the combined critical thinking and reading comprehension test scores of grade 7 students regardless of the teaching method (i.e., Equalities as Metaphors instruction or traditional language arts instruction)?

The results from this study indicated that language arts instruction had a statistical effect on the combined critical thinking and reading comprehension PARCC scores of grade 7 students regardless of the teaching method (i.e., (intervention or control group). Results from an independent samples *t*-test was found to be statistically significant t (41) = 3.13, p <. 005, d = 0.957. The independent t-test analysis results exceeded Cohen's (1988) convention for effect size .08 and indicated that language

arts instruction affects critical thinking and reading comprehension, regardless of instructional methods (see table 2).

Table 3
Intervention group *t*-test results

Group	N	Mean	Std.	T	Df	P
Pre-test	21	706.5238	19.17973	-19.186	20	.001
Posttest	21	735.9048	22.64488			

RQ2: To what extent does language arts instruction incorporating Equalities as Metaphors instruction impact the combined critical thinking and reading comprehension achievement of grade 7 students regardless of the method of instruction?

The results of a paired-samples *t*-test indicated Equalities as Metaphors instruction had a statistically significant effect on the combined critical thinking and reading comprehension skills of grade 7 students (t (21) / = -19.186, $p < .001$, $d = 1.4$). The paired-samples *t*-test allowed the researcher to examine the effect of Equalities as Metaphors instruction separate from the independent t-test, which showed the integration of the intervention and control group (See table 2 and 3).

Table 4
Control group *t*-test results

Group	N	Mean	Std.	T	Df	P
Pre-test	22	706.0455	18.52791	-9.711	21	.001
Posttest	22	715.9091	18.96591			

RQ3: To what degree does the method of language arts instruction (i.e., Equalities as Metaphors instruction versus traditional language arts instruction) affect the difference between pre-test and post-test combined critical thinking and reading comprehension test scores of grade 7 students?

Results of a paired-samples *t*-test further indicated that traditional language arts instruction had a significant effect on the combined critical thinking and reading comprehension achievement of grade 7 students (t (22) / = -9.711, $p < .001$, d = 0.526) outlined in (table 4).

The Equalities as Metaphors instructional method had a statistically significant effect on the difference between pre-test and post-test combined critical thinking and reading comprehension PARCC scores of grade 7 students (i.e., intervention versus control group). The independent samples t-test shown in table 2 indicated that both groups' integrated critical thinking and reading comprehension scores improved, regardless of the instructional method, t (41) = 3.132, p <. 005, d = 0.957. However, examining the control groups' critical thinking and reading comprehension results separate from the intervention groups' results shown in table 4 indicated the control group results failed to exceed Cohen's (1988) convention for effect size (d = 0.526). In contrast, the intervention group exceeded Cohen's (1988) convention for effect size (d = 1.4), shown respectively in Tables 3 and 4. The data results show that Equalities as Metaphors instruction significantly affected the critical thinking and reading comprehension achievement of grade 7 students versus traditional language arts instruction.

Study Limitations

The study results were limited to two classrooms in an elementary school in a Northern New Jersey urban school district. Therefore, the study may not generalize to other students in the United States. A quasi-experimental design made the random assignment of participants impossible in a school setting and presented a possible threat to external validity. The grade 7 intervention group attained higher pre-test scores than the control group. Therefore, Equalities as Metaphors instruction may not account for the difference in critical thinking and reading comprehension growth with complete certainty.

However, controlling for the higher pre-test scores, the treatment group that received Equalities as Metaphor instruction methods outperformed the control group that received traditional instruction relative to percentage growth between pre-test and post-test results. Another limitation was that data for this study came from only one elementary school, which housed a small population of middle school students. Small populations limit the generalizability of results (Singer & Strasser, 2017). A school that exclusively housed middle school students would have provided a larger sample size and possibly yielded a different result. Larger sample sizes increase the probability of detecting statistically significant effects (Field, 2009). The PARCC test was the only instrument to investigate statistical differences between the invention and control groups.

DISCUSSION

The purpose of this quasi-experimental quantitative study was to investigate the effect of Equalities as Metaphors instruction on the critical thinking and reading comprehension skills of grade 7 students in a Northern New Jersey elementary school. Using mathematical ideas as metaphors for critical thinking and reading instruction is not new. Ooura and Zahran (2018) noted that the 6 + 1 trait model impacted university students' critical thinking, comprehension, and writing skills. Aktas and Karamik (2017) observed teachers use algebraic thinking as a metaphor to model critical thinking and balanced communication. This study shows that the pre-test mean scores of students involved in the intervention group were slightly higher than those involved in the control group (706.5238 – 706.0455 = 0.4783) at the study's beginning, tables 3 and 4. Despite the difference, the pre-test results did not detract from the statistically significant performance that favored the intervention group. The difference between the intervention and control groups' post-test scores were (29.381 – 9.86 = 19.521). The intervention and control group pre-test scores were (706.5238 – 706.0455). The difference between the intervention groups' post-test scores and the intervention and control groups' pre-test scores were (19.521– 0.4783 = 19.0427). Controlling for the difference between pre-test scores of both groups, a statistically significant difference exists between the critical thinking and reading comprehension post-test PARCC scores of grade 7 students in the intervention and control group. These results align with previous mathematical models that teach critical thinking and reading comprehension.

CONCLUSION

Critical thinking and reading comprehension are foundational skills students and workers use to analyze, evaluate, and synthesize information to solve multiple contexts. In the research introduced in this study, educational leaders and employers emphasized the importance of critical thinking and reading comprehension skills to acquire and apply new information. The study results demonstrated that exposing students to a mathematical way of conceptualizing and reading text increased the critical thinking and reading comprehension performance of grade 7 students. The research presented in this study and statistical results is essential to teachers, educational leaders, principals, and employers interested in developing thinkers that can solve problems with analysis, synthesis, evaluation, and reimages new possibilities through presented information.

RECOMMENDATIONS

The tested and proven effectiveness of Equalities as Metaphors instruction in improving critical thinking and reading comprehension achievement of grade 7 students compared to traditional language arts teaching methods provided the basis for the recommended application of Equalities as Metaphors instruction to educational leaders and teachers, principals, and employers. Equalities as Metaphors instruction incorporates mathematical equalities into the teaching framework that provide a schematic or a mirror representation of the text that allows students to visualize the invisible concepts of critical thinking and reading comprehension. The researcher suggests that educational leaders adopt educational instruction that features mathematical metaphors to offer students a more visual way to

learn the complex process of critical thinking and reading comprehension. Findings in this study provide educational leaders with necessary research and data that justify implementing programs that feature a linear way to think, read and analyze text incorporated in Equalities as Metaphor instruction.

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