



Technology Enhanced Learning: Utilization of SymboLab Manipulative Instruction and Performance of Students in Quadratic Graphs

Ekemini T. Akpan ^{a*}, Gladys I. Charles-Ogan ^a, Foluke B. Eze ^b,
Uzoamaka C. Okafor-Agbala ^c and Edith C. Onyeka ^c

^a Department of Curriculum Studies and Educational Technology, Faculty of Education,
University of Port Harcourt, Port Harcourt, Rivers State, Nigeria.

^b Department of Science Education, Faculty of Education, Federal University of Otuoke,
Bayelsa State, Nigeria.

^c Department of Science Education, Faculty of Education, Nnamdi Asikiwe University, Awka,
Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Twenty first century learners are digital citizen and technologically savvy. This demands the use of innovative teaching strategies that take leverages of the affordance of digital tools. In this study, the effects of SymboLab manipulative instruction on students' performance in quadratic graph has been investigated. Three research questions and three hypotheses guided the study. The population of study consisted of all senior secondary one students across schools in Uyo metropolis, and a sample size of one hundred (100) students were purposively selected from the population. The instruments for data collection was Quadratic Performance Test. The validated instrument by experts yielded a reliability coefficient of 0.81, by method of Kuder-Richardson-21 formula. Quasi-experimental design was used for the study. Two intact classes were assigned to experimental group and a control group. The first experimental group were taught the concept of quadratic graph

*Corresponding author: Email: ekeminitakpan@uniuyo.edu.ng;

using SymboLab Manipulative Instruction, while the control group were taught quadratic graph using Concrete Manipulative Instruction. Data obtained from the study was analyzed using mean, percentages and Analysis of Covariance. The results showed that students taught quadratic graph using technology enhanced learning tool; SymboLab Manipulatives performed significantly higher than those taught using Concrete Manipulative. Gender exerted a non-significant influence on students' performance in quadratic graph between the intervention groups. Moreover, the joint effect of gender and instructional manipulatives yield non-significant influence on students' performance in the concept of quadratic graph. It was therefore recommended that technology enhanced learning tools such as SymboLab Manipulatives should be used to teach the concept of quadratic graphs in secondary schools.

Keywords: *Technology-Enhanced Learning (TEL); SymboLab manipulatives; concrete manipulatives; quadratic graphs; performance; gender.*

1. INTRODUCTION

1.1 Background of the Study

Emerging digital technology has been paving ways for robust digital media solutions that support teaching and learning of Mathematical concepts in primary, secondary, and tertiary Education. Seamlessly, the Mathematics learning space has been enriched by different digital media solutions and techno-pedagogical tools. The use of hyper-multimedia tools include instructional simulation and game, info-graphics, instructional video, online learning, mobile learning, animation strategy and so on, in the mathematics learning environment. However, digital media solutions, themselves may not contribute to effective and efficient learning of the subject, but indirectly influence learning to occur by the affordance embedded in it pedagogical explorations. Technological affordance in instructional practices, for instance, the communication and representational features forms expressivity, and dynamic interactions of mathematical concepts. These digital devices fosters learners' autonomy and independence in an environment that is responsive and adaptive to their individual learning needs as well as adaptation to the societal functions. The interdependency of pedagogical practices in Mathematics on technology has been linked to the ability of the learners to explore visual, symbolic and numerical representations simultaneously in a dynamic and interactive ways [1]. This is otherwise perceived as the ability of the learners to carry out multiple representation of the learner tasks in a flexible learning environment. Martin and Betrus [2] suggested that multiple representations promote learning for the following reasons:

(a) they highlight different aspects: hence, the information gained from combining

representations will exceed that gained from a single representation;

- (b) they constrain each other, so that the space of permissible operators diminishes;
- (c) when required to relate multiple representations to one another, the learner has to engage in activity that promotes mathematical skills and knowledge.

In spite of the existence of digital divides among users, digital tools might not supplant the role and responsibility of Mathematics teachers in the classroom. However the major challenge would be how instructional designers and teachers situate the resources and take advantage of the opportunities offered by digital resources for learning and meaning making while keeping students central to the activity and design. In this perspective, such digital resources includes the use of Dynamic Geometric Systems (DGS) which supports multimedia principles of instructional design.

1.2 The Concepts of SymboLab Manipulative in Learning Quadratic Graphs

There are dedicated technology-enhanced learning resources and applets suitable for engaging the learners during teaching of quadratic graphs. These includes Dynamic Geometry Systems such as SymboLab Manipulative. SymboLab is a flexible virtual manipulative that create ways to involve the learners during classroom delivery in mathematics, and other science related disciplines. It is an educational software resource that supports smart didactic by the use mobile devices with android operating system and supported web-based system. It was released to the public in 2011 by three Israelis – Michal Avny, Adam Arnon, and Lev Alyshayev and is managed

by a company called EqsQuest Ltd. It has been design to solve mathematical problems through a stepwise answer to questions raised by the students or educator. The application software solve mathematical and science related problems in areas such as pre-algebra, algebra, pre-calculus, trigonometry, statistics, physics, chemistry, finance, and economics. It has also become a huge database of information with over one billion math problems and explanations. As soon as you visit the Symbolab website; <https://www.symbolab.com>, then one will be able to access its basic calculator on the homepage. To get into some of the more useful parts of Symbolab (practice questions, quizzes, an unlimited notebook, a paid subscription is required. One major component of Symbolab manipulative is the graphical utility package. This graphing utility programme as shown in the (Fig. 1) has been devoted to plotting different kinds of graphs including quadratic graphs.

Generating quadratic graph using Symbolab Manipulative is a seamless process. The subject or topic, can be selected by entering the problem with the proper functions or notation, and formatting in the bar, then press go, and the answer or quadratic graph is pops up. The Graphing calculator allows users to graph a function. The users are able to zoom in or out of the graph. Next to the bar where the user type in the equation of the function, there is a table icon. Clicking on this icon will cause a window to pop-

up with a table of values of points on the graph. The users can manually change any x-value to find a y-value in the table. Users and learners can also save the output as a portable data format (PDF) or print the graph, while recording on their worksheets.

1.3 Technological Affordance and Acceptance of Symbolab Manipulatives in Mathematics

Mason [3] discussed the affordances of using Symbolab Manipulative to engage learners as follows: *Expounding*: In using Symbolab the teacher is acting as a meta-cognitive coach, by clarifying misconceptions, miscomprehensions, and situating the learning environment; ensuring the adequacy of the instructional design of the learning environment supported by Symbolab Manipulative as well as its adaption to learners previous knowledge. The effect of the action is to draw the students into focusing on the intrinsic learning content, rather than the technological fidelity of the virtual applet. *Exploration*: This is the co-action phase between the learners, and the digital tool (Symbolab Manipulative). These activities will assist students in inquiring, generating new ideas, and doing a preliminary study using prior knowledge. Scientific processing, and modelling, and simulations skills are executed during this phase. Effective interaction is enacted through aligning teacher

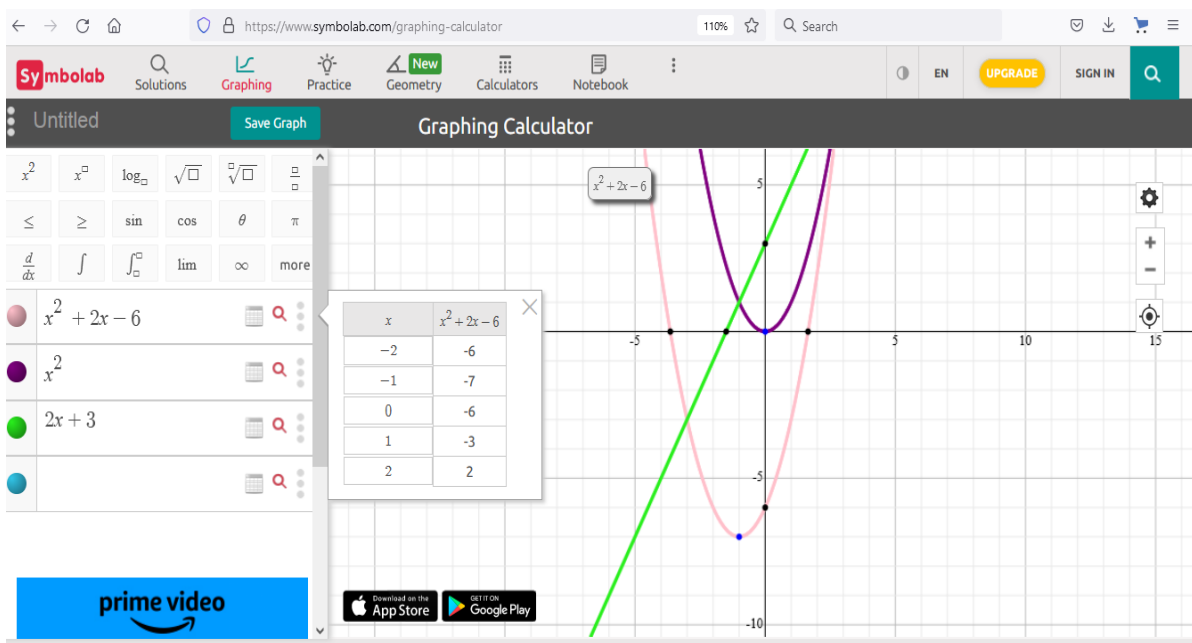


Fig. 1. Snap shot of Symbolab graphing applet

and learners' attention to actions and activities ongoing and directed to the learning content. *Explanation:* The element of student-centred learning becomes imperative through communicate of ideas, discoveries, while teachers keep engaging them with thought provoking inquiries. Appropriation of ideas, definitions, conceptual and formal understanding are imposed during this phase. *Expressing:* Students begin elaboration and transferability to real-life experiences as teachers facilitate scaffolding and fading processes. Students feeling the need to construct their own narrative, so the student mediates between the content and affordance of the manipulative. *Exercising:* The teacher mediates between the student and the content and artifacts through drill and practice. Conceptual changes are strengthen through reinforcement and worked examples. The feedback features in the manipulatives becomes useful as learners interactivity becomes maximal. *Examining:* Experts criteria are being used to test students understanding, and contents mediation between students and teacher.

SymboLab Manipulatives as an instructional resources mediate between students and Mathematical activities, students and Mathematical contents, as well as students and Mathematical representations which leads to new forms of conjecturing and reasoning. Heid [4] argued that the components of mathematical content, mathematical activity, and mathematical representation, are inseparable when analyzing the engagement of students in mathematical work using digital technology as seen in Fig. 2.

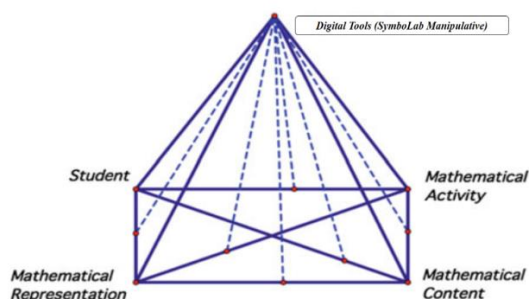


Fig. 2. Pyramid of mediated affordance of virtual manipulatives in mathematics

Fig. 2 shows a pyramidal model depicting the complex interactions of digital tools such as SymboLab Manipulatives top vertex of the pyramid) and Mathematical representation, content, and activity. Digital technology can affect

the mathematical activity in which students engage, the mathematical representations that students use, and the mathematical content to which students are exposed. Digital tools can also mediate the relationship between the student and the mathematical representation, content, or activity. Deep understanding, diagnostic inquiry skills, and mathematical creativity in unfamiliar concept such as quadratic graphs can be developed in the context of using SymboLab Manipulatives. The learning content might not be more abstract, but represented in a dynamic learning environment, and learners become immersed and manipulators of the own learning experiences.

1.4 Theoretical Perspective

The use of digital tools in learning Mathematics is underpinned by embodied cognition and principles of multimedia instructional design. In the lens of Embodied Cognition, cognitive process admits internal representations of learners' mental configuration and possesses a dual interplay of bodily interactions with the external representations. In this perspective, external representations connotes observable, physically embodied configurations in the environment (e.g., multimedia components in a digital environments) which one can access with sufficient understanding of the representations. Moreover, the interplay among representations includes internalizing external representations (e.g., interpreting quadratic graphs using symbols, and pictures) and externalizing internal representations (e.g., writing, speaking, and manipulating virtual learning objects or digital tools). Importantly, these interactions with appropriate combinations of multiple external representations using multimedia principle translates to experiential learning. Meyer [5] postulated that effective instructional design and learning takes place when the instructional environment is augmented with pictorials, images, animations, info-graphics, and simulation videos, but not words only. Meyer's principle include the following: *Principle of signaling:* Signaling reduces extraneous processing by guiding the learner's attention to the key elements in the lesson by building systemic connections between them. *Principle of coherence:* learning improves when interesting but irrelevant words and, pictures are excluded from a multimedia presentation. Learners' cognitive adaptations and synchronization are improved when cues that highlight the organization of the essential material are added

to the learning aids. *Principle of spatio-temporal contiguity*: place essential words next to corresponding graphics, diagrams, and equations on the screen or page simultaneously in proximity. *Redundancy*: reduce unnecessary content that are not linked to learners' previous knowledge. Expansive learning occurs when instructional design is bounded by the multimedia learning principles for reducing extraneous cognitive load, while seeking avenues to improve germane cognitive load [6]. Thus learner-centered approach, supported by the use of digital tools enhance could performance when multimedia principles are applied.

1.5 Empirical Perspective

Armah and Osafo-Apeanti [7] investigated the effects of graphing software; SymboLab Applets in teaching mathematics at senior secondary level. It was established that the use of technology supported applications; graphing software (SymboLab) improves academic performance of students in plotting of quadratic functions in Mathematics. An M-learning interactive app was designed and used to assess the impacts on 4-year undergraduate engineering mathematics students test performance, while using the mobile learning app and notes books [8]. The results showed that the ease and convenience of using the mobile app have a positive effect on students' autonomous learning. It was showed that app based instruction gives motivation, inferably has a positive relationship with student learning effectiveness. Tubona (2021) determines the effects of Mathway App: a digital technology supported learning strategy, on senior secondary students' attitude and performance in Mathematics in the concept of Algebra. It was found out that, there was no significant difference in performances between students that had positive attitudes toward the use of Mathway Application strategy, and those with negative attitude toward Mathway Apps. This result could be attributed to the learners' ability to visualize and develop creative skills in solving problems in algebra characterized by digital tools in the teaching and learning of Mathematics. Benning and Agyei (2016) investigated the efficacy of using Spreadsheet software as an instructional resource to teaching and learning of quadratic functions for students in Ghana. The study showed that the Spreadsheet Instructional Method served a useful pedagogical approach, impacted more on the students' performance and has the potential of improving teaching

and learning mathematics in Senior High schools.

1.6 Statement of the Problem and Justification

The effort of Educational stakeholder to expand mathematical literacy yields minimal success in our schools. A growing body of evidence shown that traditional pedagogies still dominate the primary, and education programmes and misaligned with the diverse learning opportunities offered by the use of digital technologies. Inability of instructors to explore innovative teaching approaches, and leverages afforded by technology leads to poor learning outcome. Hence, this study seek to investigate the use of technology-enhanced learning; SymboLab Manipulatives on students' academic performance in quadratic graphs in Uyo Metropolis, Akwa Ibom State.

1.7 Aim and Objectives of the Study

This study seeks to investigate the effect of SymboLab Manipulative Instruction on performance of students in quadratic graph in secondary schools. The specific objectives of the study are the following:

1. Examine the effect of SymboLab Manipulative Instruction on the performance of students in quadratic graphs.
2. Investigate the influence of gender on the performance of students taught quadratic graphs.
3. Assess the joint effect of SymboLab Manipulative Instruction and gender on performance of students in quadratic graphs.

1.8 Research Questions

1. What is the effect of PhET Manipulative Instruction and Concrete Manipulative Instruction on the performance of students in quadratic graphs?
2. What is the influence of gender on the performance of students in quadratic graphs?
3. What is the joint effect of Instructional Strategy and gender on performance of students taught quadratic graph?

1.9 Research Hypotheses

1. There is no significant difference in scores between the students taught using SymboLab Manipulative Instruction, and those taught using Concrete Manipulative Instruction in their performance in quadratic graph
2. There is no significant difference in scores between the mean performance scores of male and female students taught quadratic graph.
3. There is no significant joint effect of Instructional Strategy and gender on performance of students taught quadratic graph.

2. METHODOLOGY

This study adopts quasi-experimental research design. This design allows partial random assignment of intact classes to experimental and control groups. The total population of the study consisted of four thousand nine hundred and sixteen (4916) of senior secondary one (SS1) students with two thousand and twenty one (2021) males and two thousand eight hundred and ninety five (2895) female students of 2021/2022 academic session in Akwa Ibom State (State Secondary Education Board [SSEB], 2022). In this process, a multi-stage sampling technique was used to select three (3) secondary schools from the population of co-educational secondary schools, based on the following criteria: (i) well-equipped and functional Computer Laboratory (ii) at least one qualified Mathematics and Computer Education teachers with at least five years of teaching experience. (iii) Schools that presented students for the Senior Secondary Schools Certificate Examinations (SSCE) in the last five (5) academic sessions. On the other hand, using simple random sampling technique, a total of one hundred (100) students were selected consisting of two intact classes. Students assigned to experimental group were taught the concept of quadratic graph using SymboLab Manipulative Instruction, and student assigned to control group were taught the same concept using

Concrete Manipulative Instruction. Quadratic Graphs Performance Test (QGPT) consisting of twenty (20) multiple choice test questions were used to collect data. The instrument was validated by expert in test and measurement and reliability of the instrument was computed using Kuder-Richadson's 21 formula. The instrument yields a reliability coefficient of 0.81 and considered suitable for the study. Descriptive statistic (mean and standard deviation), effect size and inferential statistic (Analysis of Covariance-ANCOVA) have been used for data analyses.

3. RESULTS AND DISCUSSION

3.1 Presentation of Research Questions

Research Question 1: What difference exist between students taught using SymboLab Manipulative Instruction and Concrete Manipulative Instruction on their performance in quadratic graph?

Table 1 presents the descriptive statistics of the pretest mean performance scores of students taught the concept of quadratic graph using SymboLab Interactive Instruction ($n = 43, M = 61.05, SD = 14.50$), and those taught using Concrete Manipulative Instruction ($n = 57, M = 59.30, SD = 16.41$) respectively. Its describes the descriptive statistics of the post-test mean performance scores of students taught quadratic graph using SymboLab Interactive Instruction ($n = 43, M = 84.85, SD = 9.28$), and those taught Concrete Manipulative Instruction ($n = 57, M = 64.65, SD = 3.37$). The table shows respective mean gains within each group's mean performance scores when taught the concept of quadratic graphs; SymboLab Interactive Instruction ($M_g = 23.60$), and Concrete Manipulative Instruction ($M_g = 5.53$). Table 1 shows that students taught quadratic graph using SymboLab Manipulative Instruction had percentage mean gain of 38.6, higher than those students taught quadratic graph using Concrete Manipulative Instruction had percentage mean gain score of 5.53.

Table 1. Mean performance scores of students classified by instructional strategy

Instructional Strategy	Pretest			Posttest		Mean Gain M_g	Percentage Mean gain %
	n	M	SD	M	SD		
SymboLab Manipulative Instruction	43	61.05	14.50	84.65	9.28	23.60	38.66
Concrete Manipulative Instruction	57	59.30	16.41	64.82	16.85	5.53	9.33

Research Question 2. What is the influence of gender on the performance of students taught quadratic graph?

Table 2 shown the classification of the students' performance scores by gender for both pretest and post scores respectively. Table 2 shows the pretest score for male ($n = 43, M = 62.09, SD = 14.24$) and female ($n = 57, M = 58.51, SD = 16.45$), as well as the post test scores for male ($n = 43, M = 73.72, SD = 16.51$) and female ($n = 57, 73.07, SD = 17.77$) students taught quadratic graph across the three instructional strategies. There is a gain in the mean performance scores within the male ($M_g = 11.63$) and female ($M_g = 14.56$) students when taught quadratic graph. Table 2 shows that female students had higher percentage mean gain of 24.88 than their male counterpart with percentage mean gain of 18.73 respectively.

Research Question 3: What is the join effect of instructional strategy and gender on performance of students taught quadratic graph?

Table 3 shows the classification of students' mean performance scores by instructional strategy and gender for both pretest and posttest scores respectively. When using SymboLab Manipulative Instruction, Table 3 indicates the pretest score for male ($n = 18, M = 61.11, SD = 14.51$) and female ($n = 25, M = 61.00, SD =$

14.79), as well as the posttest scores for male ($n = 18, M = 84.44, SD = 10.97$) and female ($n = 25, M = 84.80, SD = 8.01$). There is a mean gain score within the male ($M_g = 23.33$) and female ($M_g = 23.80$) students' performance when taught quadratic graph using SymboLab Manipulative Instruction. Female students had a higher percentage mean gain of 39.02, than their male counterpart with percentage mean gain of 38.18.

On the other hand, when using Concrete Manipulative Instruction, Table 3 indicates the pretest score for male ($n = 25, M = 62.80, SD = 14.14.29$) and female ($n = 32, M = 56.56, SD = 17.62$), as well as the post test scores for male ($n = 25, M = 66.00, SD = 15.61$) and female ($n = 32, M = 63.90, SD = 17.95$). There is a mean gain score within the male ($M_g = 3.2$) and female ($M_g = 7.34$) students' performance when taught quadratic graph using Concrete Manipulative Instruction. Female had a higher percentage mean gain of 12.98, than their male counterpart with percentage mean gain of 5.10.

3.2 Presentation of Research Hypotheses

Hypothesis 1: There is no significant difference between the students taught using PhET Manipulative Instruction, and those taught using Concrete Manipulative Instruction in their performance in quadratic graph.

Table 2. Male and female students' performance scores in quadratic graph

Gender	Pretest			Post test		Mean Gain	Percentage mean gain
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	$ M_g $	%
Male	43	62.09	14.24	73.72	16.51	11.63	18.73
Female	57	58.51	16.45	73.07	17.77	14.56	24.88

Table 3. Mean performance scores of students classified by instructional strategy and gender

Instructional strategy	Gender	Pretest			Post-post test		Mean Gain	Percentage gain
		<i>n</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	$ M_g $	%
SymboLab Manipulative Instruction	Male	18	61.11	14.51	84.44	10.97	23.33	38.18
	Female	25	61.00	14.80	84.8	8.10	23.80	39.02
Concrete Manipulative Instruction	Male	25	62.80	14.29	66.00	15.61	3.20	5.10
	Female	32	56.56	17.62	63.91	17.95	7.34	12.98

Table 4. Summary of ANCOVA of students' performance classified by instructional strategy using pretest as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17992.991 ^a	2	8996.496	78.197	.000
Intercept	9480.840	1	9480.840	82.407	.000
Pretest	8358.254	1	8358.254	72.649	.000
Strategy	8629.065	1	8629.065	75.003	.000
Error	11159.759	97	115.049		
Total	567175.000	100			
Corrected Total	29152.750	99			

a. R Squared = 0.617. (Adjusted R Squared = 0.609) Dependent Variable: Posttest Scores

Table 4 shows a two-way analysis of covariance (ANCOVA) of performance of students taught the concept of quadratic graph using SymboLab Manipulative Instruction and those taught using Concrete Manipulative Instruction, while using pretest as the covariate. The table showed that there is significant difference in the mean performance scores of students taught quadratic graph as classified by instructional strategy [$F_{1,97} = 75.00$, $p = 0.00$ ($p < 0.05$)]. The null hypothesis was rejected which indicates a statistically significant difference between mean performances of students taught the concept of quadratic graph using SymboLab Manipulative Instruction and those taught using Concrete Manipulative Instruction.

Hypothesis 3: There is no significant difference between the mean performance scores of male and female students taught quadratic graph.

Table 5 shows a two-way analysis of covariance (ANCOVA) of the influence of gender on students' academic performance when taught the concept of quadratic graph using SymboLab Manipulative Instruction, and those taught using Concrete Manipulative Instruction, while using pretest as the covariate. Table 5 shows that

gender has no significant influence on students' academic performance when taught the concept of quadratic graph [$F_{1,97} = 0.308$, $p = 0.58$ ($p > 0.05$)]. Hence the null hypothesis was retained which indicates that there is no statistically significant influence of gender on students' academic performance when taught the concept of quadratic graph.

Research Hypothesis 3: There is no significant joint effect of Instructional Strategy and gender on performance of students taught quadratic graph.

Table 6 is the ANCOVA that determines the interaction effect of the influence of gender and instructional strategy (SymboLab Manipulative and Concrete Manipulative Instruction) on students' performance in quadratic graph. From Table 5, the instructional strategy and gender had no joint effect on students' academic performance when taught quadratic graph [$F_{1,95} = 0.074$, $p = 0.786$ ($p > 0.05$)]. Hence the null hypothesis was retained which indicates that the interaction effect of gender and instructional strategies were non-significant when students were taught the concept quadratic graph.

Table 5. Summary of ANCOVA of students' performance classified by Gender using pretest as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9426.656 ^a	2	4713.328	23.177	.000
Intercept	7626.706	1	7626.706	37.503	.000
Pretest	9416.276	1	9416.276	46.303	.000
Gender	62.730	1	62.730	.308	.580
Error	19726.094	97	203.362		
Total	567175.000	100			
Corrected Total	29152.750	99			

a. R Squared = 0.323(Adjusted R Squared = .0.308) Dependent Variable: Posttest Scores

Table 6. Summary of ANCOVA of students' performance as classified by instructional Strategy and gender using pretest as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18031.392 ^a	4	4507.848	38.507	.000
Intercept	9008.233	1	9008.233	76.949	.000
Pretest	8333.805	1	8333.805	71.188	.000
Strategy	8502.457	1	8502.457	72.629	.000
Gender	25.040	1	25.040	.214	.645
Strategy * Gender	8.700	1	8.700	.074	.786
Error	11121.358	95	117.067		
Total	567175.000	100			
Corrected Total	29152.750	99			

a. R Squared = 0.619 (Adjusted R Squared = 0.602) Dependent Variable: Posttest Scores

3.3 Discussion of Results

SymboLab Manipulatives and Performance of Students in Quadratic Graph: Students taught quadratic graph using SymboLab Manipulative performed significantly higher than students taught quadratic graph using Concrete Manipulative Instruction. The differences in performance could be attributed to the seamless learning features embedded in SymboLab Manipulative Applet. There is behavioral, cognitive and emotional engagement when students are using SymboLab Manipulatives in learning quadratic graphs. SymboLab Manipulative Instruction has been proven to be a more effective instructional strategy as compared to the use of traditional lecture method, as students' performed better while using it to learning the concept of simultaneous equations in Pakistan [9]. Armah and Osafo-Apeanti [7] supported the finding of this study when reported that the use of graphing software; SymboLab Applets in teaching mathematics at senior secondary level improves the cognitive abilities of the learners, while plotting quadratic graphs. Also, using an M-Learning Interactive Apps, Tang et al [8] affirmed the results of this finding by opting that the ease and convenience of use of mobile apps create positive effects on students' autonomous learning in Mathematics. On the contrary, to the results of this finding, Nneka [10] discovered that there is no significant difference between the mean achievement scores of pupils with dyscalculia in mathematics when exposed to explicit instruction and concrete representational abstract Strategy, while students taught using Concrete Representational Abstract strategy showed higher performance than their counterpart.

Instructional Manipulatives, Gender and Performance of Students in Quadratic Graph: It has been discussed that female students

shown high mean gain and percentages in performance score as compared to male when taught the concept of quadratic graph using SymboLab and Concrete Manipulatives respectively. On the other hand, there is no statistically significant influence of gender on students' performance in quadratic graph. Hence the manipulatives in teaching mathematics is gender responsive and inclusive. Irrespective of gender, students can explore, experiment, interpret, and manipulate the learning environment using manipulatives at equal level. This finding has been supported by the findings of Ndubisi and Arokoyu [11]. They upheld that gender has no significant effects on students' performance in learning the concepts of geometric patterns and shape, even though male performed higher than female during the experiment. Similarly, Macualay and Obafemi, [12] supported the findings of this study by reporting that male students performed better than female students in the concept of Electrolysis, but without any statistical significant difference. A contrary empirical evidence has been highlighted by Safo et al [13] in a study of the effects of computer-assisted instructional packages, and they discovered that gender has a statistically significant joint effect on students' retention, while using computer assisted instructional packages to teach the concept of geometry.

Joint Effect of Instructional Manipulatives and Gender on Performance of Students in Quadratic Graph: In one hand, female students had higher mean gain, with corresponding higher percentage mean gain than their male counterpart in quadratic graph when using SymboLab Manipulative and Concrete Manipulative respectively. On the other hand, there is no interaction effect of instructional manipulatives and gender on students' academic

performance in quadratic graph. This could happen due to multiple modal principles deployed in the design of SymboLab Manipulative Instructional strategy, as well as gender friendly effect of mathematical manipulatives. Manipulatives could facilitate germane cognitive load irrespective of gender, which in turn manifest during assessment of the learning outcome. This result corroborates to the finding in Pitchford et al (2020). They highlighted that the use of Interactive App Strategy (IAPS) in teaching Mathematics in low-income country in Sub-Saharan reduces gender disparities. They observed that the use of digital interventions can mitigate gender differences in countries where standard pedagogical instruction typically hinders girls from acquiring early mathematical skills at the same rate as male. On the contrary, Anthony et al [14] discovered that female students had a significantly higher cognitive ability than female while learning language spelling skills within the context of computer assisted drill and practice strategy [15-19].

4. CONCLUSIONS

The following conclusions were derived from the findings of this study:

1. The use of SymboLab Manipulative Instruction enhances students' academic performance in quadratic graph.
2. Male and female students performed effectively in quadratic graphs while using SymboLab manipulatives.
3. There was no significant interaction effect of gender and SymboLab manipulatives to students' academic performance in quadratic graph.

5. RECOMMENDATIONS

Based on the findings of the study, the following recommendations were made:

1. Teachers should use SymboLab Manipulative Instruction in secondary school level to teach students the concept of quadratic graphs.
2. Instructional scientist should design and produce gender inclusive and flexible learning resources such as SymboLab manipulatives for teaching of quadratic graphs.
3. Parents and guardians should provide technology enhanced learning facilities to augment and supports students' manipulative skills in learning of quadratic graphs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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