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# IMPROVING CONCEPTUAL UNDERSTANDING IN GEOMETRY THROUGH MULTIMEDIA INSTRUCTION: EVIDENCE FROM A QUASI-EXPERIMENTAL STUDY

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**Abstract**

This study evaluated the effectiveness of a computer-based educational package on improving pupils' understanding of geometry at Grade 8 students. A quasi-experimental design was employed, involving pre- and post-test assessments across experimental and control groups. Descriptive statistics indicated a substantial increase in mean scores from pre-test ($M = 3.69$, $SD = 2.96$) to post-test ($M = 7.75$, $SD = 1.77$). Normality testing using Shapiro-Wilk revealed significant deviations from a normal distribution ($p < .001$), warranting the use of both parametric and non-parametric analyses. A paired sample t-test showed a significant improvement in post-test scores ($t(149) = -21.21$, $p < .001$), a result confirmed by the Wilcoxon Signed-Rank Test ($Z = -10.98$, $p < .001$), demonstrating the robustness of the intervention's effect. However, independent t-test and Mann-Whitney U analyses showed no statistically significant difference between experimental and control group post-test scores. Despite this, the within-group comparison clearly highlighted the intervention's effectiveness. These findings underscore the potential of integrating computer-based instructional tools into the teaching of geometry to foster deeper understanding and learner engagement in junior high mathematics education.

**Keywords:** Geometry learning, computer-based instruction, educational intervention, mathematics achievement, quasi-experimental design

## 1. Introduction

Mathematics, often viewed as the foundation of scientific inquiry and technological progress, plays a critical role in both individual and national development (Chesimet et al., 2016; Kurumeh, 2006). As a discipline, it equips learners with the ability to engage in abstract thinking and problem-solving, making it indispensable to modern education. Iji (2007) emphasized that no nation aspiring for growth in science and technology can afford to overlook the importance of mathematics.

Despite its value, students frequently exhibit fear and aversion toward mathematics, leading to a lack of interest and consistently poor performance—particularly in topics like geometry and mensuration (Kurumeh, 2007). These concerns have been echoed in reports such as the West African Examinations Council (WAEC) Chief Examiner's Report, which highlights persistent low achievement levels and diminished student motivation in mathematics (Achor et al., 2015).

Geometry, a core strand of mathematics, is central to developing learners' critical thinking, problem-solving, and reasoning abilities (Pittalis & Christou, 2010). It bridges various mathematical domains and enhances visualization, conjecture, logical reasoning, and proof skills, especially among pre-service mathematics teachers (Dimla, 2018). Fujita and Jones

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(2002) categorized geometric reasoning into three cognitive dimensions: visualization, construction, and deductive reasoning. However, the abstract nature of geometric concepts often presents challenges to learners, hindering the development of effective reasoning skills (Jones, 2002).

To mitigate these challenges, instructional tools and learning resources that present realistic and relatable problems can enhance students' engagement and comprehension (Komalasari, 2012). Learning materials that are well-structured and pedagogically sound not only improve classroom clarity but also foster positive learning experiences (Hasibuan et al., 2019). Multimedia learning packages, in particular, have been shown to increase achievement by making abstract concepts more accessible and engaging (Sawangsri, 2016). Supporting this, Smith and Jones (2015) reported significant improvements in students' mathematical performance when structured learning materials were utilized compared to traditional teaching approaches.

Given these insights, the present study aims to evaluate the effectiveness of a learning package specifically designed to support Grade 8 students' understanding of geometry. By addressing known barriers to engagement and comprehension, this study seeks to contribute to the development of more effective instructional practices in mathematics education.

## 2. Methodology

### 2.1. Research Design

This study employed a quasi-experimental research design using a pre-test and post-test control group model to examine the effectiveness of an educational computer package in improving the understanding of geometry among grade 8 pupils of Manyhia D/A in the Bono Region of Ghana. This design was chosen because it allows for comparison between groups while accounting for initial group equivalence through pre-testing, even though random assignment to groups was limited due to educational setting constraints.

### 2.2. Population and Sample

The target population comprised grade 8 pupils of Manyhia D/A in the Bono Region of Ghana. A total of 150 pupils participated in the study. Participants were selected using purposive sampling, ensuring that those selected had no prior exposure to the computer-based geometry content and had similar academic performance levels based on their previous mathematics results.

### 2.3. Grouping and Matching Procedure

The pupils were matched in pairs based on prior mathematics scores to ensure comparability in ability levels. Each pair was then randomly assigned to either the control group or the experimental group. The experimental group (n = 103) received geometry instruction using the educational computer package, which incorporated interactive geometric designs and visual illustrations. The control group (n = 47) received conventional classroom instruction using textbooks and chalkboard methods.

### 2.4. Research Instruments

The primary research instrument used was a geometry achievement test, developed by the researcher in consultation with mathematics educators and aligned with the Grade 8 mathematics curriculum. The test was composed of objective and structured questions designed to measure pupils' conceptual understanding of geometry. The same test was administered before (pre-test) and after (post-test) the intervention to both groups to track progress and learning gains.

### 2.5. Intervention Procedure

The intervention was carried out over a period of four weeks. During this period, both groups received the same geometry content. However, while the control group learned through traditional instruction, the experimental group was taught using the computer-based educational package. The package included dynamic visualizations and interactive tasks designed to enhance learners' spatial reasoning and understanding of geometrical concepts.

### 2.6. Data Collection Procedure

Pre-tests were administered to both groups at the beginning of the study to establish a baseline for comparison. Following the four-week instructional period, post-tests were administered to measure the learning outcomes of each group. All test scores were recorded and compiled for analysis.

### 2.7. Statistical Analysis

In order to evaluate the effectiveness of the educational computer package on improving grade 8 pupils' understanding of geometry, both parametric and non-parametric statistical tests were used. These tests assessed the difference between pre-test and post-test scores within and between groups.

#### 2.7.1. Parametric Tests

##### 2.7.1.1. Paired Samples t-test

This test was used to compare pre-test and post-test scores within the same group to determine whether there was a significant improvement in performance over time.

**Hypotheses:**

- **Null Hypothesis ($H_0$):** There is no significant difference between the pre-test and post-test scores.

  $H_o$: $\mu_d$ = 0 (No mean difference)

- **Alternative Hypothesis ($H_1$):** There is a significant difference between the pre-test and post-test scores.

  $H_1$: $\mu_d \neq 0$

Formula:

$$t = \frac{d}{S_d/\sqrt{n}}$$

Where:

- $d$= Mean of the differences between paired scores
- $S_d$ = Standard deviation of the differences
- $n$ = Number of pairs
- $t$ = t-statistic

##### 2.7.1.2. Independent Samples t-test

This test was applied to compare post-test scores between experimental and control groups.

**Hypotheses:**

- **Null Hypothesis ($\mathbf{H_o}$):** There is no significant difference in post-test scores between the control and experimental groups.

  $H_o$: $\mu_1 = \mu_2$

- **Alternative Hypothesis ($\mathbf{H_1}$)**: There is a significant difference in post-test scores between the two groups.

  $H_1$: $\mu_1 \neq \mu_2$

Formula:

$$t = \frac{X_1 - X_2}{\sqrt{S_d^2 (\frac{1}{n_1 - n_2})}}, \quad S_d^2 = \frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}$$

Where:

- $X_1, X_2$ = Means of group 1 and 2
- $S_d^2$ = Pooled variance
- $n_1, n_2$ = Sample sizes of the two groups

### 2.7.2. Non-Parametric Tests

Due to violations of normality assumptions (as shown in the Shapiro-Wilk and Kolmogorov-Smirnov tests), non-parametric tests were also used to validate findings from the parametric tests.

#### 2.7.2.1. Wilcoxon Signed-Rank Test

Used to compare pre-test and post-test scores for the same group without assuming normal distribution.

**Hypotheses:**

- $\mathbf{H_0}$: The median difference between paired scores is zero.
- $\mathbf{H_1}$: The median difference is not zero.

**Test Procedure:**

1. Calculate the difference $d_i = X_{post} - X_{pred}$
2. Rank the absolute values $|d_i|$
3. Assign signs to ranks based on direction of difference
4. Calculate the sum of positive and negative ranks
5. The test statistic $W$ is the smaller of the two rank sums

#### 2.7.2.2. Mann-Whitney U Test

Used to compare post-test scores between the experimental and control groups without assuming normality.

**Hypotheses:**

- $\mathbf{H_0}$: The distribution of scores is the same across groups.
- $\mathbf{H_1}$: The distributions are different.

Formula:

$$U = n_1 n_2 \frac{n_1(n_2 + 1)}{2} - R_1$$

Where:

- $n_1, n_2$ = Sample sizes
- $R_1$ = Sum of ranks for group 1

A Z transformation can be applied to standardize $U$ for significance testing:

$$Z = \frac{U - \mu_u}{\sigma_u}$$

Where:

- $\mu_u = \frac{n_1 n_2}{2}$
- $\sigma_u = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$

### 2.8. Tests of Normality

To determine whether parametric tests were appropriate, the Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted:

- Both tests returned significant p-values (< 0.05) for pre-test and post-test scores, indicating non-normal distributions.
- This necessitated the use of non-parametric tests as confirmatory measures.

### 2.9. Statistical Software

All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) Version 25. Both descriptive and inferential statistics were computed, and significance was interpreted at the 5% level ($p < 0.05$).

## 3. Results

### 3.1. Descriptive Statistics

#### 3.1.1. Distribution of respondents

The participants' ages range from 12 to 15 years, with a mean age of 13.56 years and a standard deviation of 0.871, indicating a fairly tight age distribution. The skewness is approximately 0 (-.001), suggesting a symmetric distribution, while the kurtosis is -0.667, implying a distribution that is slightly flatter than normal.

The sample consists of 150 students, with 68.7% being male and 31.3% female. This shows a significant gender imbalance, with more than twice as many male students as female.

Table 1: Descriptive Statistics for Age and Sex

| Variable | N | Min | Max | Mean | Std. Dev. | Skewness | Kurtosis | Distribution (%) |
|---|---|---|---|---|---|---|---|---|
| Age (years) | 150 | 12 | 15 | 13.56 | 0.871 | -0.001 | -0.667 | |
| Sex | 150 | | | | | | | Male: 68.7%, Female: 31.3% |

#### 3.1.2. Descriptive statistics for the pre-test and post-test scores

Descriptive statistics for the pre-test and post-test scores are summarized in Table 2. The mean score before the intervention was 3.69 (SD = 2.96), while the post-test mean increased significantly to 7.75 (SD = 1.77). Skewness and kurtosis values indicate a moderate deviation from normality.

Table 2: Descriptive Statistics for Pre-test and Post-test Scores

| Measure | Min | Max | Mean | Std. Dev | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| Pre-test | 0 | 10 | 3.69 | 2.96 | 0.70 | -0.52 |
| Post-test | 4 | 10 | 7.75 | 1.77 | -0.26 | -0.72 |

### 3.2. Normality Testing

The Shapiro-Wilk and Kolmogorov-Smirnov tests (Table 3) show significant p-values ($p < .001$), indicating that both pre-test and post-test scores significantly deviate from a normal distribution. This justified the use of both parametric and non-parametric methods for validation.

Table 3: Tests of Normality

| Variable | Test | Statistic | df | Sig. |
|---|---|---|---|---|
| Pre-test | Shapiro-Wilk | .856 | 110 | .000 |
| Post-test | Shapiro-Wilk | .887 | 110 | .000 |

### 3.3. Paired Sample Comparison

A paired sample t-test revealed a significant improvement in scores from pre- to post-test ($M = -4.07$, $SD = 2.35$, $t(149) = -21.21$, $p < .001$), suggesting that the intervention significantly enhanced students' understanding.

To account for the non-normality, a Wilcoxon Signed-Rank Test was conducted. The result also confirmed a statistically significant increase in scores ($Z = -10.98$, $p < .001$), thus reinforcing the conclusion that the intervention was effective.

Table 4: Parametric and Non-Parametric Tests for Pre-Post Difference

| Test Type | Test Statistic | df | p-value | Conclusion |
|---|---|---|---|---|
| Paired t-test | t = -21.21 | 149 | .000 | Significant |
| Wilcoxon Signed-Rank | Z = -10.98 | | .000 | Significant |

### 3.4. Group Comparison: Experimental vs Control

Independent t-test results showed no statistically significant difference between post-test scores of the two groups ($t(148) = .437$, $p = .662$). Equal variance was not assumed due to Levene's test ($F = 14.85$, $p < .001$). Similarly, the Mann-Whitney U test yielded $U = 2283.5$, $p = .619$, affirming that the group differences were not statistically significant.

Table 5: Comparison of Post-Test Scores between Groups

| Group | N | Mean | SD | Test | Statistic | p-value | Conclusion |
|---|---|---|---|---|---|---|---|
| Group 1 | 103 | 7.80 | 1.96 | t-test (equal var) | t = .437 | .662 | Not Significant |
| Group 2 | 47 | 7.66 | 1.27 | Mann-Whitney U | U = 2283.5 | .619 | Not Significant |

## 4. Conclusion

The findings of this study provide substantial evidence that the use of an educational computer package significantly improves pupils' understanding of geometry at the Basic Five level. The paired samples t-test revealed a statistically significant increase in post-test scores compared to pre-test scores, with a mean difference of -4.067 ($p < 0.001$), indicating marked improvement in performance after the intervention. Furthermore, the results of the non-parametric Wilcoxon Signed-Rank Test confirmed the statistical significance of this improvement, reinforcing the reliability of the findings despite slight deviations from normality in the data distribution. While the independent samples t-test showed no statistically significant difference between the two groups (control and experimental), the within-group analysis clearly demonstrated that students benefited more when exposed to the computer-based instructional method. The implication of these results is that incorporating interactive, visual learning tools into the teaching of geometry can enhance conceptual understanding and engagement among primary school pupils. The integration of technology in mathematics instruction should therefore be considered a valuable strategy for curriculum improvement in basic education.

### Ethical Considerations

Approval was obtained from the school authority and consent was secured from parents and guardians of the participating pupils. Participants were informed about the purpose of the study, and confidentiality of their information was guaranteed. Participation was voluntary, and pupils were allowed to withdraw at any stage of the study without any penalty.

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