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Effectiveness of 5E Instructional Model on Students' Performance in Mathematics Non-routine Problem

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study's aim was to determine the impact of the 5E instructional model on students' performance in non-routine mathematics problems. The population was made up of junior high school students in Oforikrom municipality, Ghana's Ashanti Region. The study used a quasi-experimental non-equivalent design. A total of 84 students were drawn at random from Oforikrom's two Junior High Schools. The experimental and control groups were assigned at random to the two schools. The experimental group was taught using the 5E instructional model, while the control group received traditional instruction. In both the pretest and posttest, students were given a non-routine achievement test consisting of mensuration, percentages, and equations. The independent sample t-test, Mann-Whitney U and Wilcoxon W tests, and Kruskal Wallis test were used to analyze the results. The study's findings showed that the 5E model has a positive effect on students' performance in non-routine mathematics problems. It also found that there is a significant difference between the control and experimental groups in favour of the experimental group. Furthermore, there was no significant difference in performance between male and female students in the

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experimental group. Finally, the study discovered no significant difference in the experimental group's performance based on the topics.

Keywords: 5E model; non-routine; performance in mathematics; pretest; posttest.

1. INTRODUCTION

The primary focus of the Ghanaian Mathematics curriculum is problem-solving, in which students apply what they have learned in the classroom to real-world problems. This could mean that students' ability to understand and apply mathematics to real-world problems influences many of their decisions in life [1]. That is, the goal of mathematics as a subject is to teach students how to solve simple real-life problems using mathematical concepts rather than to improve their calculation skills or follow rigorous computations.

The government of Ghana has made mathematics a compulsory subject for all pre-tertiary students. One of the core competencies that students are expected to acquire after completing pre-tertiary is the ability to apply mathematical concepts to solve non-routine problems. However, students find it difficult to solve non-routine mathematics problems and often try to avoid them in exams. This could be the primary reason for Ghanaian students' performance poorly in international exams such as Trends in International Mathematics and Science Study (TIMSS). It can therefore be concluded that students' non-routine problem is a global one.

For example, Mwei and Mwei [2] investigated senior high school teachers’ sense-making in non-routine problem solving and discovered that secondary school teachers have the following issues in non-routine problem solving: lack of understanding of the non-routine problem, inability to select appropriate heuristics in solving the non-routine problem and inability to look into a final look back. The issue is that if teachers who are supposed to teach problem-solving have these issues, how much more will their students have? It's not surprising, given that most teachers purposefully avoid teaching these non-routine problems in their classes.

Furthermore, Kurniati [3] discovered that pre-service mathematics teachers lacked critical thinking dispositions relevant to truth-seeking in non-routine problem-solving. This simply means that pre-service teachers are incapable of reasoning through non-routine problems in order to solve them. Akyüz [4] discovered that mathematics teacher candidates performed poorly in non-routine problem-solving, particularly as the problems became more complex.

A similar finding was confirmed by Heidari and Rajabi [5], who found that fourth-grade students could perform mathematical calculations in relation to a non-routine problem but could not progress past the first stage of the problem-solving procedure. This situation is similar to the findings of in Ghanaian college of education, which revealed that pre-service teachers in Ghanaian Colleges had generally low proficiency in non-routine word problem-solving [6]. Wilmot et al. [6] also found that the majority of respondents in Ghana's senior high schools and junior high schools were unable to solve most non-routine problems.

Many researchers have focused on the causes of students' inability to solve non-routine problems [7], the development of conceptual understanding in problem-solving [8], teaching strategies for non-routine problems [9,10], and so on. Others have suggested using a constructivist approach to problem-solving as well as cooperative teaching strategies [11]. However, the use of the 5E instruction model in assisting students to solve non-routine problems has received little attention in the Ghanaian educational space despite the fact that the 5E model has been shown to assist students in acquiring conceptual knowledge, procedural knowledge and procedural flexibility for understanding mathematical concepts, all of which can improve mathematical learning when used appropriately.

The 5E model has been used in a variety of subject areas and has been shown to improve students' academic performance. For example, Magsalay et al. [12] discovered that teaching through 5E constructivism is effective in improving upper primary school students' mathematics performance. Furthermore, Tuna and Kacar [13] discovered that the 5E instructional model made the study of sine rule application more fun, practical, interactive, and interesting, and improved students' academic performance when compared to the traditional teaching strategy. When compared to the traditional instructional strategy, the 5E instructional model was more effective in improving students' trigonometry performance [13]. The assertion that teachers who effectively implement the 5E instructional model can improve students' creativity, views on the nature of science, and academic achievement supports the positive effect of 5E instructional on students' academic performance.

Cakır [14] also found that the 5E instructional model has a positive effect on Turkish students' academic performance, attitude toward science, and science process skills in his study. This means that the model not only improves students' academic performance but also fosters a positive attitude toward the study of various disciplines. This performance could be attributed to students' active participation in the teaching and learning situations. Several studies have found that the 5E model improves students' academic performance [15-19]

The 5E instructional model is the constructivism approach that is influenced by Vygotsky's social constructivism as well as Ausbel's meaningful learning theory [20]. It was founded on the premise that students learn best when they are actively involved in the teaching and learning process. When students actively construct knowledge for themselves rather than passively receive information, they are engaging in active learning. The 5E in the instructional model refers to the five phases and the initials of each phase. The 5E model has five phases: Engage, Explore, Explain, Elaborate, and Evaluate [21]. The 5E instructional model places a premium on the following:

i. Enter / Engage: Quick activities or queries that promote curiosity and elicit prior knowledge are used by the teacher to get students interested in a new concept and reveal their prior knowledge.
ii. Exploration: Students engage in activities like laboratory work, group discussions, hands-on activities, role-playing, and logic while using exploration, but they also explore issues and carry out preliminary research.
iii. Explanation: Here, the teacher can directly introduce a concept, procedure, or skill, allowing students to infer their comprehension or keep track of their correct and incorrect knowledge based on the teacher's explanations.
iv. Elaborate: Students attempt to expand their newly organised knowledge in order to elaborate on their conceptual understanding and elaboration skills.
v. Evaluation. The teacher can track the students' progress toward achieving the learning objectives by evaluating their comprehension and ability during the evaluation process [22,21].

1.1 Research Questions

The research was guided by the following research questions;

1. What is the effect of 5E model on student performance between the control group and the experimental group?
2. What effect does the 5E model have on student performance as far as gender is concerned?
3. What impact does the 5E model have on student performance in general?

1.2 Research Hypothesis

Three research hypotheses guided this study. They are;

1. H01: There is no significant difference between the control group and the experimental group.
2. H02: There is no significant difference between male and female students in the post-test.
3. H03: There is no significant difference in students' post-test scores based on the topics.

2. METHODOLOGY

The study used a quasi-experimental non-equivalent design. This is due to the researcher's goal of investigating the impact of the 5E instructional model on the academic performance of junior high school students in Mathematics. The population consisted of the two junior high schools in Oforikrom municipality, in Ashanti Region. The random sampling technique was used to select two Junior high schools in the Oforikrom municipality for the study to avoid bias. Oforikrom was chosen for this study due to its proximity to the researcher's place of work and thus providing enough time to conduct the study in the selected Junior High schools. Furthermore, Form 2 students were chosen because the topics that the researcher deemed difficult for students to investigate are in Form 2. The study included 85 students in total. This group consisted of 44 students from Junior High School A and 41 students from Junior High School B, with 42 males and 43 females. A teacher-created test was developed and used for the study to test learning outcomes in mensuration, equations, and percentages. These were made up of 20 different test items.

The items were adapted from previously validated items such as past questions from West African Examinations Council (WAEC) Basic Education Certificate Examinations and Trends in International Mathematics and Science Study (TIMSS) achievement tests. Two mathematics teachers from the two selected Junior High Schools validated the content validity of the instruments. In addition, the syllabus for Junior High School Mathematics was used to prepare the test items. To ensure the construct validity of the items, the researcher piloted the instrument in a Junior High School in Ejusu Municipality. To ensure the internal reliability of the test, the split-half and reliability coefficients were estimated with two main assumptions in mind: (i) The two halves must almost have the same content and (ii) the two halves must almost have the same standard deviation. It was discovered that the two have similar content because they have nearly the same standard deviations (standard deviation for the first half = 0.866 and standard deviation for the second half = 0.875).

The reliability coefficient for the entire test was 0.756, and the Equal-length Spearmen-Brown coefficient calculated was 0.850, indicating that the items were very reliable. Prior to the experiment, the students were given a printed exam that lasted 60 minutes. Following the experiment, a posttest was conducted to determine the efficacy of the two approaches. The same questions were used for both the pretest and the posttest. The pre-test and post-test examination conditions were identical. Prior to the study, the two selected Junior High School students were assigned at random to the experimental and control groups. The control group included 41 students from School A, while the experimental group included 44 students from School B. Before the study, the two groups were pretested to ensure that there was no academic disparity between them. This also aided the researcher in determining that the two groups were equivalent. The experimental group was taught using the 5E instructional model, while the control group was taught using the traditional approach. The traditional teaching method is a teacher-centered method which takes place within the four walls of the classroom which involves oral presentation of topic and reply to short questions from the audience (Bonner, 1999). Both groups were taught in eight weeks.

3. RESULTS AND DISCUSSION

The researcher performed a normality test on the data before analyzing it. This helped the researcher choose an appropriate instrument for data analysis. The data's normality was determined using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Table 1 displays the normality test results for both the pre-test and post-test scores of the conventional and experimental groups.

According to the results in Table 1, the pre-test scores of both the conventional and experimental groups are normally distributed at P = 0.05. That is, the P-value of the Kolmogorov-Smirnov is less than 0.05 and the Shapiro-Wilk test value is greater than 0.05 at P = 0.05 in both the conventional and experimental groups' pre-test scores. However, both the Kolmogorov-Smirnov and Shapiro-Wilk results of the conventional and experimental groups are significant at P = 0.05 for post-test scores. This demonstrates that both the conventional and experimental groups' post-test scores are not normally distributed. This meant that the data required both parametric and non-parametric tests in order to be analyzed.

Table 1. Normality test of the pretest and posttest scores of the two groups

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pretest Score (Experimental group)	.138	41	.047	.968	41	.293
Pretest Score (Conventional group)	.146	41	.003	.975	41	.489
Posttest Score (Experimental group)	.264	41	.000	.817	41	.060
Posttest Score (Conventional group)	.151	41	.019	.920	41	.071

a. Lilliefors Significance Correction

Test for the differences between the conventional group and the experimental group pretest scores.

To find out whether the two groups (Conventional and Experimental groups) are homogenous, an independent sample t-test was used to compare the pre-test scores of both groups as shown in Table 2.

Table 2 compares the pretest and posttest scores of the control and experimental groups. Table 2 shows that there is no statistically significant difference in mean scores between the control (mean = 8.659, SD = 2.661) and experimental groups (mean = 8.523, SD = 2.698) at t (83) = 0.416, p = 0.816. Because the two groups have similar characteristics, they are homogeneous. This aided in comparing the post-test test results of the experimental and control groups. This also indicated that prior to the experiment, students in both the experimental and control groups performed at the same level in non-routine problems.

3.1 Achievement of Students in Control and Experimental Groups

Mann-Whitney U and Wilcoxon W, which are the equivalent of independent sample t-tests, were used to determine whether there was a difference in the mean scores of students in the control and experimental groups. The results are shown in Tables 3 and 4.

The experimental group’s mean rank (54.56) appears to be the same as the control group's mean rank (30.60). As a result, the total number of ranks in the control group (1254.50) was less than the total number of ranks in the experimental groups (2400.50). However, to see if there was a difference in the mean rank of the control and experimental groups, the data was tested using the Mann-Whitney U and Wilcoxon W tests, as shown in Table 4.

The Mann-Whitney U (393.500) and Wilcoxon W (1254.500) results are both significant Z = -4.495, p = 0.00 at the 0.05 alpha level. This demonstrates that there is a significant difference in mean scores between the experimental group and the control group in favour of the experimental group. At P = 0.05, this indicated that the experimental group's mean rank (2400.50) is higher than the control group's mean rank (1254.50). Students in the experimental group outperformed students in the control group. This means that the 5E model of instruction is more effective than the traditional method of teaching at improving students' performance in non-routine problems. That is, the 5E model of instruction has a positive effect on students' academic performance in non-routine math problems. This is not surprising given that the 5E model of instruction has been shown to be effective in improving students' performance in physics, chemistry, mathematics, and science.

The high mean of the experimental group in Mathematics non-routine problems, however, surprised the researcher, as it has been shown that students perform poorly in world or non-routine problems. This could be because the 5E constructivist approach was more enjoyable, interesting, and interactive than the traditional class [23]. This finding is consistent with the findings of Omotayo and Adeleke [24] who discovered a significant difference between the experimental group and the control group after the experimental group was exposed to the 5E instructional model in favour of the experimental group. The following studies highlight similar findings that indicate that the 5E instructional model improves students' academic performance in Mathematics [13,12,25,23].

Table 2. Comparison of the pretest scores of the conventional and the experimental group

	Groups	N	Mean	Std. deviation	t	df	Sig
Pretest scores	Conventional Group	41	8.659	2.661	.416	83	.816
	Experimental Group	44	8.523	2.698	.407		

Table 3. Mean rank of the control and experimental group in the posttest

	Groups	N	Mean rank	Sum of ranks
Posttest	Control	41	30.60	1254.50
	Experimental	44	54.56	2400.50
	Total	85		

Table 4. Mann-Whitney U and Wilcoxon W test comparing control and experimental group posttest scores

	Post-test scores
Mann-Whitney U	393.500
Wilcoxon W	1254.500
Z	-4.495
Asymp. Sig. (2-tailed)	.000

3.2 Post-test Achievement of Students Based on Gender

This hypothesis was tested using Mann-Whitney U and Wilcoxon W which are the equivalent of independent sample t-tests as shown in Table 5 and Table 6.

The Female mean rank (24.27) appears to be higher than the Male mean rank (19.94). As a result, the sum of female ranks (631.00) is higher than the sum of male ranks (359.00). However, to determine whether there is a difference in the mean rank of the male and females, the data were tested using the Mann-Whitney U and Wilcoxon W tests, as shown in Table 6.

The Mann-Whitney U (188.00) and Wilcoxon W (359.00) results are not significant at the 0.05 alpha level Z = -1.116, p = 0.264. This demonstrates that there is no statistically significant difference between the mean scores of male and female students. That is, the male mean rank (19.94) and female mean rank (24.27) are statistically equal. This demonstrates that both male and female students performed equally well on the post-test exams. This means that the 5E model of instruction, regardless of gender, is effective in improving students' performance in non-routine problems. This means that the 5E model does not favour gender disparities and can help bridge the gap between male and female students' performance in Mathematics, particularly in non-routine problems. The findings contradict the assertion that there is a significant difference in Physics performance between male and female students after using the 5E instructional model [26].

Furthermore, when comparing the critical thinking skills of students in Mathematics after exposure to the 5E instructional approach, it was discovered that there is a significant difference between male and female students' critical thinking skills, even though both cases improved. In addition, the finding also contradicts the study conducted by Heidari and Rajabi [5] who investigated the relationship between students' performance in non-routine problems according to grade and gender. The finding indicated that male students performed well in non-routine problem tests than female students.

3.3 Students' Post-test Scores Based on the Three Topics

To determine whether there is a difference between experimental group posttest scores based on topics, Kruskal-Wallis Test is employed. The results of the mean ranks and Kruskal-Wallis Test are shown in Table 6 and Table 7.

Table 7 compares the test scores of students in the experimental group in various topics (Mensuration, Equation, Percentages). The results show that there is no statistically significant difference in the mean rankings of the three topics X^2 (2) =1.372), p=0.504. This demonstrates that the students' mean rank in the three topics is statistically equal. This means that using 5E improves students' performance in Mathematics regardless of the aspect or topic. Despite the fact that there are minor differences in the mean ranks of the experimental groups' scores in the three topics, such differences are not statistically significant. This is consistent with [13]'s findings, which indicated that the 5E learning model has the potential to improve students' performance in trigonometry and its application. This is also consistent with the findings that the 5E model can improve students' academic performance in integrated science topics [27].

Table 5. Mean rank of male and female students in the experimental group posttest scores

	Gender	N	Mean Rank	Sum of Ranks
Experimental Group Posttest Scores	Male	18	19.94	359.00
	Female	26	24.27	631.00
	Total	44		

Table 6. Mann-Whitney U and Wilcoxon W test comparing control and experimental group posttest scores

Gender	Posttest score
Mann-Whitney U	188.000
Wilcoxon W	359.000
Z	-1.116
Asymp. Sig. (2-tailed)	.264

Table 7. Kruskal Wallis test comparison of the posttest scores of the experimental group based on topic (mensuration, equation, percentages)

	Topics	Mean rank	Chi-square	df	Asymp. Sig.
Experimental Score (Posttest)	Mensuration	65.48			
	Percentages	71.47	1.372	2	.504
	Equation	62.56			
	Total				

4. CONCLUSION AND RECOMMENDATION

The current study's findings indicate that the 5E model has a positive effect on students' performance in non-routine mathematics problems. Furthermore, regardless of gender, the 5E instructional model improves students' performance in non-routine problems. This means that the 5E model is appropriate for teaching both male and female non-routine mathematics problems. Finally, the study found that the 5E model can improve students' performance in non-routine problems across all three topics studied. It is thus suggested that teachers use the 5E model when teaching non-routine problems. The current study focused on the use of the 5E instructional model on non-routine problems in junior high school. Other studies in senior high schools can be conducted to assess the effects of the 5E model on students' performance and interest in non-routine problems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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