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Effect of Flipped Classroom Instruction on Pre-Service Mathematics Teachers' Knowledge of Geometry

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Abstract

This research examines the effect of flipped classroom instruction on the knowledge of geometry of pre-service mathematics teachers in Ghana. A total of 290 teachers from six intact classes across four colleges of education were selected for the research. The study employed a quasi-experimental design to compare the effectiveness of the flipped classroom instruction against the conventional teaching methods. The sampling techniques included purposive and convenience. The instrument employed to collect data was tests. Pre-service mathematics teachers in the flipped classroom groups received interactive video lessons and other online resources to review before class, while the control groups followed the conventional teaching methods. Pre-test scores were analyzed using a one-way analysis of variance (ANOVA), showing no significant difference in knowledge of geometry between the experimental and control groups. However, the post-test ANOVA results indicated a significant difference with $p < 0.001$. Further analysis using Bonferroni's Post hoc test confirmed significant differences between the control groups and all experimental groups, showing that the experimental groups performed better than the control groups, and with Cohen's d effect size being large, the study recommends integrating the flipped instructional strategies into geometry instruction by mathematics teachers to promote active engagement, independent learning, and improved academic performance in geometry among pre-service mathematics teachers.

Keywords: flipped classroom instruction; pre-service teachers; knowledge of geometry;

Introduction

Geometry serves as a cornerstone in mathematics as it helps in the development of spatial reasoning, problem-solving aptitude, and critical thinking prowess. Its significance echoes through various mathematics curricula, of which Ghana is not an exception, where geometry has seamlessly been integrated into the mathematics curriculum from the elementary stages through to tertiary education. The basic school level mathematics lays the groundwork, which focuses on geometric construction and the elucidation of properties embedded in quadrilaterals and polygons (National Council for Curriculum and Assessment [NaCCA], 2020). Proceeding to the senior high level, the scope of geometric exploration expands from Plane Geometry I, which delves into the elaborate details of angles at a point, parallel lines intersected by a transversal, and the external angle theorem, to Plane Geometry II, where circle theorems take center stage (Curriculum Research and Development Division [CRDD], 2010). The Transition from the senior high school to the Colleges of education, the curriculum sums up geometry within their pedagogical

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horizon, catering for two unique cohorts: all first-year students and students specializing in Junior High School (JHS) education. In their first-year, the curriculum encompasses a multifaceted approach, comprising topics such as angles at a point, angles within parallel lines, and the rich tapestry of triangles, quadrilaterals, and polygons. Additionally, students engage with the realm of three-dimensional shapes, contrasting polyhedral forms, and exploring the realm of congruence, similarity, and the practical applications of Pythagoras' theorem.

However, even though geometry is taught throughout Ghana's educational level, a number of studies from Ghana and other countries show that students consistently struggle to understand and apply geometric concepts effectively (Acquah & Alhassan, 2018; Hangül & Cezikturk, 2020; Ubi & Igiri, 2018). These hurdles manifest across all educational tiers, from basic schools to tertiary institutions, including colleges of education (Amidu & Nyarko, 2019; Asemani et al., 2017; Pinamang & Coffie, 2017). These difficulties could result from the ineffective conventional teaching strategies used by mathematics teachers. When it comes to the teaching of geometry, teachers are required to possess the skills of visualization (Žakelj & Klančar, 2022), the conventional teaching methods provide limited support in this regard.

There is therefore a need for teachers to diversify their methods of teaching, and one of the ways that has proven to work in other settings is flipped classroom instruction. The flipped classroom instruction is a form of blended learning where/students/are/allowed to engage with content at their own pace before class and participate in active learning during class time (Bouchrika, 2026). This study was conducted at the colleges of education, which are tasked with training teachers to teach at the basic school. The problems reported by Acquah & Alhassan, 2018; Tuğba et al., 2020; Ubi & Igiri, 2018 motivated the researcher to explore ways to enhance pre-service teachers' knowledge for teaching geometry using the flipped classroom instruction. Specifically, the study was set out to answer the question: What is the effect of flipped classroom instruction on pre-service mathematics teachers' knowledge of geometry?

Methods

Research Design and Sampling

The study adopted a quantitative method in which a quasi-experimental design was employed. As indicated by Creswell and Creswell (2018), a quasi-experimental design allows researchers to explore the impact of an intervention on subjects without random assignment of individual participants into experimental and control groups. Based on the objective of the study, the researcher deemed it fit to employ a quasi-experimental design to examine the effect of flipped classroom instruction (FCI) on pre-service mathematics teachers' knowledge in geometry.

The study utilized a convenience sampling technique to select four colleges of education, after which six intact classes containing pre-service teachers who are majoring in mathematics were purposively sampled for the study. A pre-test was administered to all groups to assess pre-service teachers' initial knowledge in geometry. The researcher, after marking the scripts, grouped the classes into two control groups and four experimental groups; these groupings were based on the mean scores of the various classes, with the classes with the highest mean scores being assigned to the control groups. The use of intact classes was consistent with the quasi-experimental nature of the study, in which

individual participants were not randomly reassigned to newly constituted groups.

Implementation of the Intervention

The experimental and control groups were taught selected geometry topics using different instructional methods. The experimental groups were taught using flipped-classroom instruction designed around the tenets of Kolb's Experiential learning theory, while the control groups received conventional face-to-face instruction. The instruction for the experimental groups was organized into pre-class, face-to-face, and post-class phases. Prior to each in-class session, the pre-service mathematics teachers were made to access interactive learning materials which were developed by the researcher using the Xerte software. The materials comprised short instructional videos, animations, interactive quizzes, guiding questions, and practice exercises. All were designed to introduce various concepts in geometry before the face-to-face lesson. For example, for the concepts of lines and circles, the pre-class materials were videos on gradient and equations of lines, a video demonstration on how to derive the equation of a circle, some animations illustrating the interaction between lines and circles, a short quiz, and some practice problems.

During the face-to-face sessions, in-class time was devoted primarily to active learning. The pre-service mathematics teachers worked in groups of eight (8), engaged in peer teaching, solved geometry problems, and finally participated in reflective discussions. The mathematics tutors acted mainly as facilitators by guiding the activities, providing continuous feedback, and giving brief explanations when misconceptions emerged. This structure reflected Kolb's experiential learning cycle by providing opportunities for learners to engage with experiences, reflect on their learning, connect their observations to formal geometric concepts, and apply the concepts to problems. In particular, guided practice, instructor feedback, and short mini-lectures were used to connect students' discussions to formal geometric theories and proofs.

During the post-class session, the experimental groups undertook problem-solving assignments, reflective activities, and practical application tasks to consolidate their learning. These activities provided massive opportunities for the pre-service teachers to apply the newly acquired knowledge in geometry to practical situations and consider how such concepts could eventually be taught in their own classrooms.

On the other hand, the control groups were taught the related geometry concepts through the conventional face-to-face approach, which followed a traditional lecture-based method. At the end of the instructional period, both the experimental and control groups were made to answer the same post-test to determine whether their knowledge in geometry differed following exposure to the respective instructional approaches.

Research Instruments

A test (pre-test and post-test) was chosen as an instrument for collecting data for this study. Test items for the pre-test and post-test were designed by the researcher and administered before and after the treatment, respectively. Each set of questions comprises four questions. All questions were based on the topics listed in the colleges of education handbook: Pythagoras' theorem, the equation of a circle, the relationship between lines and circles, circle theorems, and polygons.

Validity and Reliability measures

A thorough inspection was done by the researcher and other experts in the area of geometry at the College of Education in Ghana to ensure that the test items were

strictly aligned with the College of Education mathematics curriculum. The researcher then piloted the instrument in a college of the same characteristics as the colleges used for the main study, and then employed the inter-rater reliability, where three tutors from other colleges were made to mark the scripts. A Fleiss' kappa reliability value of 0.72 was obtained, which indicated that raters agreed substantially (Landis & Koch, 1977).

Data Collection Procedure and Data Analysis

Before the implementation of the flipped classroom instruction, all groups were subjected to a pre-test to measure pre-service teachers' knowledge of geometry. The test results were then subjected to a one-way analysis of variance (ANOVA) to check if the mean scores of the various groups were statistically different. A p-value of 0.001 was recorded, which indicates that their mean scores are statistically different. A Bonferroni Post-Hoc Test revealed that the mean scores of two groups were statistically different from the other four groups. The two groups obtained mean scores of 5.63 and 5.5, while the other groups obtained mean scores below 4.20, on the basis of their performance in the pre-test, the researcher labeled the groups with the highest mean scores as control groups and the other four groups as experimental groups 1-4.

Results

Results from the one-way analysis of variance test revealed that participants who underwent the flipped classroom instruction had outperformed participants who were subjected to the conventional teaching methods, with the Bonferroni post-hoc test revealing that the mean scores of all experimental groups were statistically different from those of the control groups. Also, an Eta squared was also calculated to be 0.541, indicating a large effect size according to Cohen (1988). Table 1 shows the Bonferroni Post-Hoc test.

Table 1 Bonferroni Post-Hoc Test for Post-Test scores

Comparison	Mean Difference	p-value	Interpretation
Experimental Group 1 vs Control Group 1	-5.728	.000	Significant
Experimental Group 1 vs Control Group 2	-6.290	.000	Significant
Experimental Group 2 vs Control Group 1	-6.111	.000	Significant
Experimental Group 2 vs Control Group 2	-7.498	.000	Significant
Experimental Group 3 vs Control Group 1	-6.111	.000	Significant
Experimental Group 3 vs Control Group 2	-6.189	.000	Significant
Experimental Group 4 vs Control Group 1	-6.498	.000	Significant
Experimental Group 4 vs Control Group 2	-7.576	.000	Significant

Discussion

The study explores the effect of flipped classroom instruction on the knowledge of geometry of pre-service mathematics teachers in Ghana. The findings revealed that, overall, students had a weak understanding of geometry before the experiment. However, after receiving flipped-classroom instruction, the experimental groups demonstrated significant improvement in their knowledge of geometry compared with the control groups. The study compared post-test scores of the experimental and control groups using a one-way analysis of variance (ANOVA). The results indicated that the experimental groups, who learned through the flipped classroom approach, significantly outperformed the control groups. This is

consistent with research by Gundlach et al. (2017), which found that university students in a flipped classroom performed better than those in traditional lecture-based settings. Likewise, Bhagat et al. (2016) observed significant academic improvement in students who received flipped instruction in a trigonometry class, further noting that the flipped approach enhanced students' enjoyment and enthusiasm for mathematics.

According to Kolb, these improvements in students' achievement can be credited to how flipped learning integrates reflective observation, enabling students to process new concepts at their own pace before class, with active participation, allowing them to apply their knowledge through hands-on activities. Subsequently, the improvement in post-test scores suggests that students gained from the opportunity to investigate mathematical concepts in detail, enhancing their understanding through interactive learning. This finding is in line with previous studies by Yang et al. (2019) and Strelan et al. (2020), which revealed that flipped learning greatly enhances students' performance in mathematics.

However, these results contradict research findings from (Clark, 2015), who reported that while flipped classrooms encourage more engagement as well as communication, they do not necessarily guarantee higher academic achievement. The discrepancy may be due to the variations in how the flipped classroom instruction was implemented, differences in student readiness, or the nature of the subject matter being taught. In light of the massive endorsement of the flipped classroom instruction, it is evident that the flipped classroom instruction supports the teaching and learning of mathematical concepts, with a focus on knowledge of geometry, because it enhances visualization (Žakelj & Klančar, 2022), which is a principal skill in the teaching and learning of geometry.

Conclusion

In conclusion, the study has demonstrated that flipped classroom instruction positively influenced the knowledge of geometry of Pre-service Mathematics Teachers in Ghana. Although the participants initially showed weak understanding of geometric concepts, students who were taught with the flipped classroom instruction showed tremendous improvement in their post-test performance compared to their counterparts who were taught through the conventional instructional methods. The significant differences observed between the experimental and control groups show that flipped classroom teaching can serve as an effective pedagogical approach for enhancing students' understanding of geometry.

The findings further support the assumptions of David Kolb's Experiential Learning Theory (Kolb, 1984), particularly the importance of reflective observation and active experimentation in the learning process. By allowing students to engage with instructional materials before class and participate in collaborative problem-solving activities during class, the flipped classroom created opportunities for deeper conceptual understanding and meaningful learning experiences. This interactive learning environment appears to have strengthened students' visualization and reasoning abilities, which are essential components of geometric understanding.

Overall, the study provides empirical evidence that flipped classroom instruction can improve the teaching and learning of geometry in mathematics education. The study therefore recommends that mathematics educators and teacher training institutions should consider integrating flipped instructional strategies into geometry instruction to promote active engagement, independent learning, and improved

academic performance among Pre-service Mathematics Teachers.

Disclosure statement/ Conflicts of Interest

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in this study.

Data Availability Statement

The data presented in this study are available on request from the author since this research was conducted on students, for which their teachers gave consent.

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