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*Research Article*

# The impact of GeoGebra-assisted problem solving based on variation theory on students' motivation in geometry

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The study examined ninth-grade students' motivation and its components in learning geometry through variation theory-based, GeoGebra-assisted problem-solving instructional approaches. A total of 125 students and 4 mathematics teachers were purposively selected for the study. A quasi-experimental research design was employed. Quantitative data were collected using a motivation questionnaire. Four classes were selected, three of which served as treatment groups—Treatment Group 1, Treatment Group 2, and Treatment Group 3—each receiving a specific instructional intervention. One comparison group was also included, assigned using simple random sampling techniques. Both pre-test and post-test motivation items were administered before and after the intervention, respectively. ANCOVA and paired samples *t*-tests were used for data analysis. The findings revealed a significant mean difference between pre-test and post-test scores of students' motivation and its components in all treatment groups, unlike the comparison group. Notably, the mixed-treatment group showed the largest mean difference, indicating a substantial improvement in students' motivation toward learning geometry. It is recommended that teachers receive support and training in implementing variation theory-based GeoGebra problem-solving approaches to enhance students' motivation in geometry. School administrators should prioritize the integration of GeoGebra software by establishing computer labs, and government officials are encouraged to promote and support the implementation of technology in schools.

**Keywords:** GeoGebra, motivation, problem-solving approaches and learning geometry, variation theory

## 1. Introduction

Learning achievement is influenced by student's intrinsic and extrinsic motivation. Piaget believed that motivation is the best to gain students achievement. Student's motivation comes when they do work to gain experience from it. This shows that motivation serve as stimulant for students achievement (Asare et al., 2025; Ofem et al., 2024).Designing instruction that motivates students to learn is a fundamental challenge among educators in science, technology, engineering, and mathematics [STEM] disciplines (Leal et al., 2022; Wigfield et al., 2016). The contribution of motivation significantly affected student's mathematics achievement. The contribution of student's motivation in mathematics enhanced the achievement of mathematics by 32.0%(Atnafu, 2012) Findings across theoretical orientations indicate that students' perceptions of success in mathematics are highly influential in forming their motivational attitude. Motivations toward mathematics are highly stable over time, and are influenced by their teacher action and attitude (Middleton & Spanias, 1999).

Thus, one teaching approach that could be used to develop students' motivation is that supporting the lesson using GeoGebra. The Mathematics software available in the market or even online has facilitated the task of the teacher to impart knowledge beneficial to the students. However, it depends on the teacher to utilize existing materials without the need to allocate extra time to develop other teaching aids. GeoGebra software has a positive impact on students' achievement and interest. The students also have positive perceptions on GeoGebra software in terms of enthusiasm, confidence, and motivation. This software should be introduced to

Mathematics educators so that students can explore the world of Mathematics in a wider and make the students able to think critically and creatively (Arbain & Shukor, 2015)

Another teaching approach to enhance student's motivation in learning geometry is that using variation theory. Variation Theory embraced a different notion of motivation from social motivational theory. It is centred on the association of the object of learning and this enables students in establishing relevance structure for the learning so that it can be seen as significant for students. In a learning situation, if students can see the relationship between the object of learning and their daily life experience, it will promote their understanding and invoke favourable reaction to the object of learning (Lo, 2012).

Therefore, this study integrating Geogerba on the Variation theory problem solving approaches in order to see its impact on students' motivation and components of motivation (intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation, attention and satisfaction) in learning geometry.

## 2. Problem Statement

Currently, students' achievement in mathematics in Ethiopia has been declining over time, becoming a critical challenge for the country's educational system. According to Wole et al. (2025), national learning assessments have consistently shown that the average mathematics scores of grade 8 students remain below the 50% proficiency benchmark. Several key factors contribute to the declining quality of mathematics education, including lack of problem-solving skills, low motivation, and negative attitudes toward mathematics. Motivation and self-efficacy are crucial predictors of learning outcomes, with emotional factors such as self-efficacy and attitudes exerting a direct influence on mathematics achievement (Tessema, 2022). Although the 1994 Education and Training Policy and related guidelines advocate for a learner-centered approach, its practical implementation remains inconsistent, with many classrooms still relying on teacher-centered practices (Bekele, 2023).

To bring students motivation and to enhance good academic achievement in Ethiopia there is a struggle in changing the curriculum based and book cantered learning environment thought the use of technology in secondary education specifically. But due to teacher's inability to use digital technology, lack of technology infrastructure and limited technical support affect to integrate teaching learning process (Abera Berhanu, 2013; Aragaw, 2018)

According to Ethiopian National Learning Assessment, the majority of students are unable to score 50% and above which is predicted by the Ministry of Education even after finishing each grade cycle. The fifth National Learning Assessment yielded a score of 35.2 in mathematics for students in grade 8. In addition to being below the 50% achievement level set by the Education and Training Policy of Ethiopia and showing a consistently declining trend in their achievement from year to year, this result is also the lowest when compared to other subjects, indicating that students are unable to achieve the necessary minimum competencies (National Educational Assessment and Examinations Agency [NEAEA], 2016).Likewise, findings from Ethiopian students' national learning assessment, which was administered in April 2009 to students in grades 10 and 12, indicated that students are not able to meet the required competencies. It is also a more recent requirement, as revealed by the education roadmap's findings, which highlight the significance of placing a strong emphasis on technology-enhanced learning at all levels. The integration of contemporary technological innovations has the potential to address certain challenges in education, foster the development of conceptual understanding and problem-solving abilities, and boost student motivation and engagement (Mulugeta et al., 2015). In order to address the previously mentioned issues and current advancements, this research will employ instruction based on variation theory with support from GeoGebra. The GeoGebra software was selected because of the new Curriculum of Ethiopian genera education program incorporate the use of this software for technological support of the lesson.in addition to this, it is free software that can be downloaded in http://www.GeoGebra.org/, as the official website. This implies one of the best suggested ones is GeoGebra software ( Dasari &Tamam, 2021).

The main objective of this study will be to explore the effect of variation theory based GeoGerba assisted problem-solving instructional approach on 9th grade students' motivation. Based on the objective, the study will attempt the following research questions.

RQ 1) Are there significant mean gain differences in grade 9 students' pre-test and post-test motivation and components of motivation in learning geometry within each of interventions and control groups?

RQ 2) Are there significant posttest mean differences in students' motivation and components of motivation in learning geometry among the three treatments and comparison groups using the pre-test as a covariate?

## 3. Literature Review

A motive is a reason for doing something. Motivation is concerned with the strength and direction of behavior and the factors that influence people to behave in certain ways. The term 'motivation' can refer variously to the goals individuals have, the ways in which individuals chose their goals and the ways in which others try to change their behavior (Davidovitch & Dorot, 2023; Uka & Prendi, 2021). Motivation in education can have several effects on how students learn and how they behave towards subject matter. It can: Direct behavior toward particular goals, Lead to increased effort and energy, Increase initiation of, and persistence in, activities, enhance cognitive processing, determine what consequences are reinforcing, and Lead to improved performance. Because students are not always internally motivated, they sometimes need situated motivation, which is found in environmental conditions that the teacher creates (Tohidi & Jabbari, 2012)

It is possible to measure student's motivation in mathematics from different perspectives. For example, Fiorella et al. (2021) point out a feasible measure for capturing secondary students' motivation to learn in mathematics, presenting sound validity and reliability evidence and revealing varied motivation with in a multidimensional context. These are intrinsic motivation, self-efficacy, utility value, test anxiety and self-regulation. Similarly extrinsic motivation affect students engage in an academic activity for instrumental reasons, such as gaining a college degree in mathematics in order to improve employment prospects in actuary science or engineering (Miller et al., 1988). Thus intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation attention and satisfaction are components of motivation which measure it in one way or another way.

Utilization of Variation theory based instruction yields students to have higher motivation on attention and satisfaction. A multivariate analysis of variance was conducted to explore the impact of instructional strategy on students' overall motivation and its subscales. The result indicated that there was a statistically effect of instructional strategy (group) on Students' Overall Motivation (Yeshanew et al., 2024). This result contradicted to (Wong et al., 2010) which found that students in Hong Kong (urban region) did not yield positive motivational reaction toward Variation theory based instruction treatment.

Variation theory positively affects student's motivation while it is integrating with other approaches. The integration of variation theory with Guided Inquiry-Based Instruction effectively enhances students self-beliefs SB in learning solid geometry, thereby addressing the educational challenges faced by Ethiopian students (Yeshanew et al., 2024). According to Ahlquist & Gynther ( 2020) variation theory helps in order to engage on tasks in a constructive way The use of Variation Theory Based Strategy in teaching and learning of mathematical concept incorporate students motivation in the class and it enable them to have good problem solving ability (Jing et al., 2017).

GeoGebra is one of the most popular software for teaching mathematics. Still, after 20 years, it is shown its usefulness and easiness for both teachers and students. Effectiveness of GeoGebra not limited only in Student achievement but also in student motivation and the sub-scales ARCS. It contributes to other studies of computer-assisted learning. Since Mathematics has more abstract concepts, using technology helps to make it more visual and understandable for learners (Hosseini et al., 2022). According to Murni et al., (2017) who found that using GeoGebra-assisted problem-based learning can help students to solve problems and improve their attitudes toward mathematics. Variation theory of teaching approaches encourage students to take responsibility for their own learning to have more power over that learning (Cheng, 2016)

Learning geometry thought Geogebra provides different important: (1) learning mathematics on circle object using Geogebra is effective for improving creative thinking ability of the students, (2) learning mathematics on circle object using Geogebra is effective for improving visual thinking ability students, (3) learning mathematics on circle object using Geogebra is more effective for improving creative thinking ability and visual thinking ability than conventional methods (Wulanningtyas, 2020). GeoGebra supported learning with an integrated approach has higher inspiration and is more engaged in certain geometrical tasks than students uncovered to conventional paper-pencil instruction. These strategies energized the secondary school understudies to memorize the points by visualizing abstract geometrical concepts. Therefore, employing a collaborative approach integrated with GeoGebra might progress students motivation to memorize geometry relative to other directions strategies (Bache et al., 2024).

Dogan and Içel (2011) study whereby it was observed that GeoGebra based activities encouraged higher order thinking skills, and had a positive effect in motivating students toward learning. Students enjoyed on learning mathematics much more when using GeoGebra and were able to form better connections between previous learning and new learning. However, some students reported they were not so confident when using the GeoGebra software (Shadaan & Eu, 2013).

## 4. Method

### 4.1. Research Design

It is known that researching a true experiment to conduct educational research is difficult because the variable cannot be fully controlled and randomization is not easy. As a result of this non-equivalent quai-experiment, educational research emerged as an alternative. The main reason for using a non-equivalent quasi-experimental research design with a pre-test and post-test is that students in the schools were assigned to groups by school administrators at the beginning of each school year, and students could not be randomly assigned to groups as in a real experiment. Cresswell (2010) noted that when a study lacks the full control of the timing of experimental stimuli that make a true experiment possible, such a situation can be collectively considered a quasi-experimental design. In particular, non-equivalent groups mean that participant characteristics may not be equal between control and experimental groups, and therefore participants' experiences may differ during the study. Therefore, this study recommends using a non-equivalent control group quasi- experimental research design

The design has one comparison group ( conventional instruction without any intervention of instruction) and three treatment groups with subjected to intervention with variation theory and GeoGebra (mixed), intervention with variation theory and intervention with GeoGebra. Consequently, the three intervention groups were: Variation theory based GeoGebra problem-solving instructional approach [TG1]; Variation theory based problem solving instructional approach [TG2], GeoGebra problem-solving instructional approach [TG3] and a comparison group [CG]. The pre-test and posttest will be given for all groups.

Table 1
*Classification of Groups for the treatments*

| *Groups* | *Pre-test* | *Treatment* | *Post test* |
|---|---|---|---|
| Treatment group1 (TG1) | $O_1$ | $X_1$ | $O_2$ |
| Treatment group2 (TG2) | $O_1$ | $X_2$ | $O_2$ |
| Treatment group3 (TG3) | $O_1$ | $X_3$ | $O_2$ |
| Comparison Group (CG) | $O_1$ | | $O_2$ |

In Table 1, $O_1$ means that a pre-test given to all groups before the interventions and $O_2$ means that a post-test given to all groups after the interventions. The variables; $X_1$, $X_2$, and $X_3$ were treatments given to group-1 (TG1), group2 (TG2) and group3 (TG3) respectively.

### 4.2. Population and Sampling

The study was carried out on ninth-grade students in Addis Ababa, Ethiopia. The rationale for choosing this grade is that secondary education begins in grade nine, and this level lays the groundwork for grades that follow. The caliber of secondary education determines success in postsecondary education. For this reason, students at this level of education must be prepared with the particular knowledge and abilities that form the foundation for further study.

After choosing the sub city for the intervention and comparison group by lottery, four schools were chosen using simple random sampling. This is because, according to Cohen et al. (2010), the researcher should have to choose similar groups as much as possible even though differences between groups naturally occur in nonequivalent quasi-experimental research designs.

### 4.3. Instrument

Various data gathering instruments were used to collect the data. This study used mathematics motivation questionnaire as its data collection methods. Motivation questionnaires in learning Mathematics [MQLM] were tested from different sub scales like intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation, attention and satisfaction.

A motivation questionnaire can be used to understand which situations may increase or decrease students motivation and help enhance learning in mathematics. These types of questionnaires aim to determine how conditions found in the classroom could affect student's motivation. Motivational questions will be used two times as pre-test before intervention and posttest after intervention.

MQLM target students' beliefs, values, self-regulation strategies, and performing in mathematics. According to (Wigfield et al., 2016), MQLM focused on secondary students because decreases in mathematics motivation at this age are more pronounced compared to other academic domains. Those constructs of MQLM will be responded on a Likert scale weighted 1=Strongly Disagree, to 5=Strongly Agree. The measurement items of mathematics learning motivation will be adapted from Fiorella et al. ( 2021) and some are modified by the researcher.

### 4.4. Validity and reliability of the instrument

In this study content validity was determine by using panel discussion with mathematics teachers and supervisors. Setting up a panel of expert/ user and getting them to comment on the instrument while the researcher developing is a good way of doing it (Muijs, 2013). Therefore, content and face validity of instrument were check using expert's opinion from mathematics teachers, psychology and curriculum and instruction. Finally, correction will make by considering the feedbacks and recommendation obtained from the experts.

Factor analysis was used to categorize and reduce a large number of motivational variables into fewer factors. In this regard, an exploratory factor analysis was performed using principal axis factoring and varimax rotation to assess the underlying structure for the thirty five items of the Students' motivation in Learning Geometry Scale. Seven factors were requested, and based on the existing literature; the items were designed to index seven such as intrinsic value; self-efficacy; utility value; test anxiety; extrinsic motivation; attention; and satisfaction in learning Geometry.

To see practicability of the instruments and reliability of instruments, pilot test was conducted at selected schools in Addis Ababa City Administration. The final version of data collection instrument was piloted for 40 students from grade 9 and using the result obtained from the pilot. Therefore, the Cronbach's alpha of the Students' Motivation and components motivation in Learning Geometry Scale at the pilot study were checked. That are, the pilot results of Cronbach's alpha coefficients for motivation was .922 and components of motivation such as for intrinsic value was .974; self-efficacy was .912; utility value was .929; test anxiety was .907; extrinsic motivation was .883; attention was .930; and satisfaction was .918; at which all values indicated greater than .70, which are in the acceptable range.

After all instruments passes all the above process and necessary revision made, the final of the test were administered as pretest and posttest to determine student's motivation before and after intervention.

### 4.5. Data Analysis

Data collected from different sources were analyzed quantitatively using appropriate statistical analysis method. In analyzing the data Statically Package for Social Science version 20 software will be used. Since the data was normally distributed, parametric statistics were employed. That is the data fulfills assumptions of parametric tests. Thus mean, standard deviation, paired t-test, ANOVA or ANCOVA, were used.

## 5. Results

### 5.1. Mean Gain Differences in Motivation and Its Components within Groups

In order to answer the first research question first check whether there are significant differences in the mean of pre-tests of students' motivation in learning geometry among the three interventions such as Variation theory based GeoGebra problem-solving instructional approach; Variation theory based problem solving instructional approach, GeoGebra problem-solving instructional approach and control groups. To check this researcher use ANOVA test. To do so the assumption of ANOVA had been fulfilled. These are; the data is continuous and normally distributed, the data are independent since the intervention had been conducted in different school in which there is no chance for the respondent to communicate each other and the dependent variable has the same variance across groups.

Table 2
*The descriptive statistics of pre-test of students' motivation and components of motivation in learning geometry by groups*

| *Dependent variables* | *TG1* | | | *TG2* | | | *TG3* | | | *CG* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | *Mean* | *SD* | *N* | *Mean* | *SD* | *N* | *Mean* | *SD* | *N* | *Mean* | *SD* |
| Pre-motivation | 34 | 3.69 | .483 | 35 | 3.49 | .56 | 29 | 3.33 | .58 | 27 | 3.45 | .757 |
| Post-motivation | 34 | 4.16 | .516 | 35 | 3.85 | .59 | 29 | 3.72 | .68 | 27 | 3.36 | .623 |
| Pre-intrinsic | 34 | 3.75 | .69 | 35 | 3.63 | .92 | 29 | 3.41 | .77 | 27 | 3.35 | 1.07 |
| post-intrinsic | 34 | 4.38 | .627 | 35 | 4.17 | .71 | 29 | 3.86 | .88 | 27 | 3.24 | .81 |
| Pre-self-efficacy | 34 | 3.58 | .576 | 35 | 3.61 | .76 | 29 | 3.19 | .914 | 27 | 3.20 | 1.03 |
| Post-self-efficacy | 34 | 4.25 | .68 | 35 | 4.03 | .75 | 29 | 3.88 | .90 | 27 | 3.19 | .85 |
| Pre-utility-value | 34 | 3.79 | .72 | 35 | 3.81 | .73 | 29 | 3.59 | .85 | 27 | 3.61 | .99 |
| Post- Utility-value | 34 | 4.44 | .64 | 35 | 4.13 | .77 | 29 | 4.07 | .80 | 27 | 3.40 | .74 |
| Pre-test anxiety | 34 | 3.86 | .46 | 35 | 3.30 | 1.15 | 29 | 3.62 | 1.02 | 27 | 3.76 | .89 |
| Post-test anxiety | 34 | 3.11 | .91 | 35 | 2.76 | .86 | 29 | 2.80 | .69 | 27 | 3.67 | .90 |
| Pre-extrinsic | 34 | 3.46 | .65 | 35 | 3.15 | 1.04 | 29 | 3.01 | .81 | 27 | 3.37 | 1.16 |
| Post-extrinsic | 34 | 4.26 | .56 | 35 | 3.79 | 1.03 | 29 | 3.86 | .90 | 27 | 3.33 | 1.05 |
| Pre-attention | 34 | 3.73 | .64 | 35 | 3.41 | .91 | 29 | 3.42 | .87 | 27 | 3.23 | .96 |
| Post-attention | 34 | 4.30 | .59 | 35 | 4.06 | .89 | 29 | 3.87 | .83 | 27 | 3.33 | .78 |
| Pre-satisfaction | 34 | 3.64 | .66 | 35 | 3.49 | 1.01 | 29 | 3.06 | 1.01 | 27 | 3.60 | 1.02 |
| Post-satisfaction | 34 | 4.37 | .56 | 35 | 3.99 | .94 | 29 | 3.72 | .96 | 27 | 3.34 | .72 |

Table 2 indicates that students' pre-motivation and pre-components of motivation in learning geometry are above the neutral value (mean = 3) and below the agreement value (Agree = 4). Highest result was observed in students in group TG1 of variation theory based GeoGebra problem-solving instructional approach in all students' pre-motivation and pre-components of motivation; and lowest result was observed in students of group TG3 of GeoGebra problem-solving instructional approach in students' pre-motivation, pre-self-efficacy, pre-utility value, pre-extrinsic motivation, and pre-satisfaction, and CG of comparative group in students' pre-intrinsic motivation and pre-attention.

Similarly, Table 2 indicates that for all students' post-motivation and post-components of motivation in learning geometry are above the neutral value (mean = 3) and some are still above the agreement value (Agree = 4) except for post-test anxiety. Highest result was observed in students in group TG1 of variation theory based GeoGebra problem-solving instructional approach (TG1) in all students' pre-motivation and pre-components of motivation except post-test anxiety; and lowest result was observed in students of comparison group CG in all students' pre-motivation and pre-components of motivation except post-test anxiety. It can be clearly seen from the table that there are increments from pre-test to post-test in all intervention groups (TG1, TG2, & TG3) of students' motivation and components of motivation except test anxiety that is there is a decrease from pre-test to post-test in test anxiety. But for comparison group, there are decrements from pre-test to post-test in students' motivation and components of motivation except attention that is there is an increment from pre-test to post-test in attention.

The following table showed that whether or not there were significant differences between the groups in their motivation and components of motivation in learning geometry before the intervention. The assumptions for ANOVA satisfied, that is the observations are independent, the data is normal and there was homogeneity of variance among the group.

Table 3
*ANOVA test on pre-test of students conceptual Understanding in learning geometry scores by groups*

| *Variables* | | *Sum of Squares* | *df* | *Mean Square* | *F* | *p* |
|---|---|---|---|---|---|---|
| Pre- motivation | Between Groups | 2.096 | 3 | .699 | 1.986 | .120 |
| | Within Groups | 42.573 | 121 | .352 | | |
| | Total | 44.668 | 124 | | | |
| Pre-intrinsic | Between Groups | 3.207 | 3 | 1.069 | 1.423 | .239 |
| | Within Groups | 90.905 | 121 | .751 | | |
| | Total | 94.112 | 124 | | | |
| Pre- self-efficacy | Between Groups | 4.835 | 3 | 1.612 | 2.384 | .073 |
| | Within Groups | 81.819 | 121 | .676 | | |
| | Total | 86.654 | 124 | | | |
| Pre-utility value | Between Groups | 1.281 | 3 | .427 | .638 | .592 |
| | Within Groups | 80.991 | 121 | .669 | | |
| | Total | 82.272 | 124 | | | |
| Pre- test anxiety | Between Groups | 6.135 | 3 | 2.045 | 2.438 | .068 |
| | Within Groups | 101.493 | 121 | .839 | | |
| | Total | 107.628 | 124 | | | |
| Pre-extrinsic | Between Groups | 3.993 | 3 | 1.331 | 1.553 | .204 |
| | Within Groups | 103.679 | 121 | .857 | | |
| | Total | 107.672 | 124 | | | |
| Pre- attention | Between Groups | 4.028 | 3 | 1.343 | 1.867 | .139 |
| | Within Groups | 87.030 | 121 | .719 | | |
| | Total | 91.058 | 124 | | | |
| Pre- satisfaction | Between Groups | 6.197 | 3 | 2.066 | 2.394 | .072 |
| | Within Groups | 104.393 | 121 | .863 | | |
| | Total | 110.590 | 124 | | | |

Table 3 describe that the summary result of one way Analysis of variance of groups on motivation and its components pretest to learn geometry. There were no statistically significant mean difference between groups on motivation ($F(3, 121) = 1.986$, $p = .120$); intrinsic motivation ($F(3, 121) = 1.423$, $p = .239$); self-efficacy ($F(3, 121) = 2.384$, $p = .073$); utility value ($F(3, 121) = 0.638$, $p = .592$); test anxiety ($F(3, 121) = 2.438$, $p = .068$); extrinsic motivation ($F(3, 121) = 1.553$, $p = .204$); attention ($F(3, 121) = 1.86$, $p =.0.139$) and satisfaction ($F(3, 121) = 2.394$, $p = .072$) in learning geometry since $p > .05$.

The next step is to check whether there is a significant difference between pretest and posttest motivation results in each intervention and comparison groups. In order to check this difference paired sampled *t*-test is used. Before starting the analysis, check the assumptions of paired sample *t*-test. The assumptions are fulfilled, that is the independent variable is dichotomous and its levels (or groups) are paired, or matched, in some way, and the dependent variable is normally distributed as indicated above. Therefore the following table showed that the difference between students motivation before and after the intervention.

Table 4

*Paired samples t-test on mean gains of the pre-test and post-test of students' motivation and components of motivation in learning geometry by groups*

| *Mean gain of Subjects* | *Group* | *Paired Differences* | | *t* | *df* | *p* |
|---|---|---|---|---|---|---|
| | | *M* | *SD* | | | |
| Motivation: | TG1 | .47 | .61 | −4.82 | 33 | <.001 |
| Post-pre | TG2 | .36 | .68 | −3.16 | 34 | .003 |
| | TG3 | .39 | .39 | −5.39 | 28 | <.001 |
| | CG | .09 | .49 | .915 | 26 | .369 |
| Intrinsic value: | TG1 | .65 | .93 | −4.10 | 33 | <.001 |
| Post-pre | TG2 | .54 | 1.15 | −2.75 | 34 | .009 |
| | TG3 | .45 | .89 | −2.69 | 28 | .012 |
| | CG | .10 | .99 | .542 | 26 | .593 |
| Self-efficacy: | TG1 | .69 | .84 | −4.75 | 33 | .000 |
| Post-pre | TG2 | .42 | 1.11 | −2.25 | 34 | .031 |
| | TG3 | .69 | .913 | −4.07 | 28 | <.001 |
| | CG | .01 | .83 | .046 | 26 | .964 |
| Utility value: | TG1 | .71 | .85 | −4.83 | 33 | <.001 |
| Post-pre | TG2 | .32 | .92 | −2.06 | 34 | .047 |
| | TG3 | .48 | .73 | −3.49 | 28 | .002 |
| | CG | .21 | .91 | 1.19 | 26 | .246 |
| Test anxiety: Post-pre | TG1 | -.89 | .66 | 7.89 | 33 | <.001 |
| | TG2 | -.54 | 1.34 | 2.38 | 34 | .023 |
| | TG3 | -.83 | 1.14 | 3.92 | 28 | .001 |
| | CG | .09 | .469 | 1.07 | 26 | .295 |
| Extrinsic motivation: | TG1 | .84 | .88 | −5.57 | 33 | <.001 |
| Post-pre | TG2 | .64 | 1.15 | −3.28 | 34 | .002 |
| | TG3 | .86 | .90 | −5.14 | 28 | <.001 |
| | CG | .04 | .83 | .233 | 26 | .818 |
| Attention: | TG1 | .63 | .88 | −4.19 | 33 | <.001 |
| Post-pre | TG2 | .65 | 1.08 | −3.57 | 34 | .001 |
| | TG3 | .45 | .87 | −2.76 | 28 | .010 |
| | CG | -.09 | .84 | −.597 | 26 | .556 |
| Satisfaction : | TG1 | .76 | .89 | −4.95 | 33 | <.001 |
| Post-pre | TG2 | .50 | 1.21 | −2.45 | 34 | .019 |
| | TG3 | .66 | .85 | −4.13 | 28 | <.001 |
| | CG | .26 | .89 | 1.50 | 26 | .144 |

*Note.* Variation theory based GeoGebra problem-solving instructional approach; Variation theory based problem solving instructional approach, GeoGebra problem-solving instructional approach and a comparison group.

Table 4 shows that the mean difference on student's motivation and components of motivation scales on learning geometry of pretest to post test on the three intervention and comparison groups. Students given a treatment with variation theory based GeoGebra problem-solving instructional approach had the significant highest mean gain from pre-test to post-test in motivation (mean gain = 0.47), intrinsic value (mean gain = 0.65), self-efficacy (mean gain = 0.69), utility value (mean gain = 0.71), extrinsic motivation (mean gain = 0.84) and satisfaction (mean gain = 0.76) since $p < 0.5$, except test anxiety and attention; that is test anxiety is least mean gain (mean gain = −0.89) in variation theory based GeoGebra problem-solving instructional approach group, and attention is highest for variation theory based problem solving instructional approach (mean gain = 0.65).

Students given a treatment with GeoGebra problem-solving instructional approach had the next second level significant in mean gain from pre-test to post-test in motivation (mean gain = 0.39), self-efficacy (mean gain = 0.69), utility value (mean gain = 0.48), test anxiety (mean gain = −0.83), extrinsic motivation (mean gain = 0.86) and satisfaction (mean gain = 0.66) since $p < .05$, except intrinsic value and attention; that is intrinsic value is the second level in mean gain for variation theory based problem solving instructional approach (mean gain = 0.54), and attention is the second level in mean gain for variation theory based GeoGebra problem-solving instructional approach (mean gain = 0.63).

Students given a treatment with Variation theory based problem solving instructional approach had the next third level significant in mean gain from pre-test to post-test in motivation (mean gain = 0.36), self-efficacy (mean gain = 0.42), utility value (mean gain = 0.32), test anxiety (mean gain = −0.54), extrinsic motivation (mean gain = 0.64) and satisfaction (mean gain = 0.50) since $p < .05$, except intrinsic value and attention; that is for GeoGebra problem-solving instructional approach the intrinsic value (mean gain = 0.45) and attention (mean gain = 0.45) are the third level in mean gain.

Students for comparison group did not have the significant difference and had least mean gain from pre-test to post-test in motivation (mean gain = 0.09), intrinsic value (mean gain = 0.10), self-efficacy (mean gain = 0.01), utility value (mean gain = 0.21), extrinsic motivation (mean gain = 0.04), attention (mean gain = −0.09) and satisfaction (mean gain = 0.26) since $p > .05$, except test anxiety that is test anxiety is highest for comparison group (mean gain = 0.09), but not significant difference since $p > .05$.

The next research question was to answer the existence of significance difference between the groups after the interventions once the pre-motivation of students in learning geometry were observed as a covariant.

### 5.2. Group Differences in Posttest Motivation Controlling for Pretest

In order to answer the second research question whether there are significant differences in students' motivation and components of motivation in learning geometry among the three interventions and control groups using the pre-test as a covariate, ANCOVA test was manipulated after the assumption was verified.

The covariates are measured before to the intervention manipulation to avoid scores on the covariates being changed by intervention, and they are not substantially connected with one another, as previously mentioned. Furthermore, the covariates are also measured rather consistently. These findings back up some of ANCOVA's assumptions. The other assumptions, such as observation independence, normality, homogeneity of variance, and linearity between covariates and dependent variables at each level of the independent variables are fit with the data. The following table represented the means of each group once the covariate(s) has been controlled and not controlled (Adjusted and Unadjusted).

Figure 1 shows the pre and post motivation scores along learning geometry. The data shows students improve their motivation in learning geometry. Table 5 shows whether a significance difference exists or not in terms of each variable.

According to Table 5, both the adjusted and unadjusted post-test mean scores for students' overall motivation and its components were reported, with pre-test scores controlled. The table shows that whether or not the post-test scores are adjusted, the mean values for students' motivation and its components remain largely unchanged across groups, with only minor variations observed in some cases. To determine whether these observed differences are statistically significant, reference should be made to Table 6.

Figure 1
*Average motivation scores on pre motivation and post motivation results*

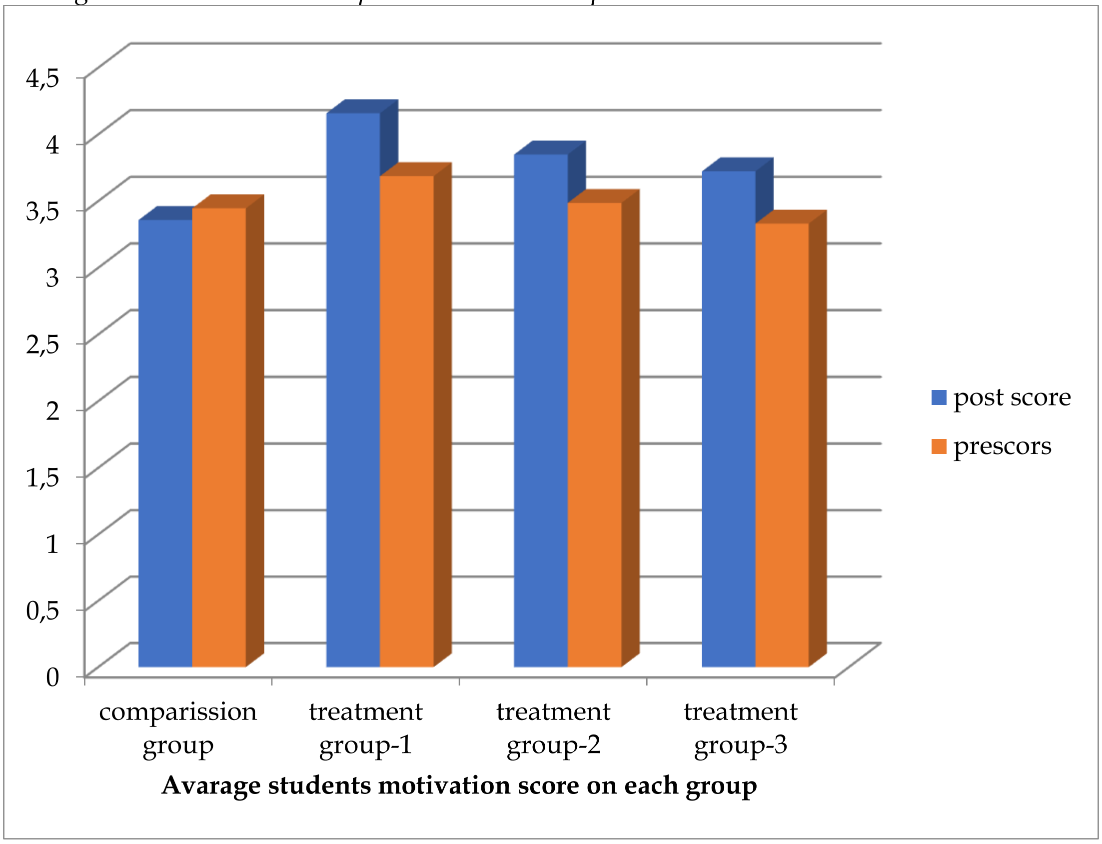


Table 5
*Adjusted and Unadjusted Means and Variability on the Three Groups for students' motivation and components of motivation in learning geometry Using Pre-test as a Covariate*

| *Variable* | *Group* | *Unadjusted* | | | *Adjusted* | |
|---|---|---|---|---|---|---|
| | | *N* | *M* | *SD* | *M* | *SE* |
| Motivation | TG1 | 34 | 4.17 | .45 | 4.17 | .087 |
| | TG2 | 35 | 3.85 | .5 9 | 3.85 | .080 |
| | TG3 | 29 | 3.72 | .6 8 | 3.88 | .091 |
| | CG | 27 | 3.36 | .62 | 3.36 | .091 |
| Intrinsic value | TG1 | 34 | 4.40 | .54 | 4.42 | .125 |
| | TG2 | 35 | 4.17 | .71 | 4.17 | .119 |
| | TG3 | 29 | 3.86 | .88 | 3.93 | .133 |
| | CG | 27 | 3.24 | .81 | 3.32 | .138 |
| Self-efficacy | TG1 | 34 | 4.27 | .56 | 4.28 | .126 |
| | TG2 | 35 | 4.03 | .753 | 4.04 | .124 |
| | TG3 | 29 | 3.88 | .90 | 3.99 | .135 |
| | CG | 27 | 3.19 | .85 | 3.30 | .139 |
| Utility value | TG1 | 34 | 4.50 | .5 2 | 4.50 | .113 |
| | TG2 | 35 | 4.13 | .78 | 4.10 | .112 |
| | TG3 | 29 | 4.07 | .80 | 4.14 | .123 |
| | CG | 27 | 3.40 | .74 | 3.44 | .127 |
| Test anxiety | TG1 | 34 | 2.97 | .73 | 2.79 | .135 |
| | TG2 | 35 | 2.76 | .86 | 2.79 | .123 |
| | TG3 | 29 | 2.80 | .69 | 2.80 | .129 |
| | CG | 27 | 3.67 | .90 | 3.55 | .136 |

Table 5 continued

| *Variable* | *Group* | *Unadjusted* | | | *Adjusted* | |
|---|---|---|---|---|---|---|
| | | *N* | *M* | *SD* | *M* | *SE* |
| Extrinsic motivation | TG1 | 34 | 4.26 | 1.03 | 4.23 | .153 |
| | TG2 | 35 | 3.79 | 1.03 | 3.83 | .135 |
| | TG3 | 29 | 3.86 | .90 | 3.99 | .154 |
| | CG | 27 | 3.33 | 1.05 | 3.26 | .154 |
| Attention | TG1 | 34 | 4.39 | .58 | 4.37 | .135 |
| | TG2 | 35 | 4.06 | .89 | 4.076 | .123 |
| | TG3 | 29 | 3.87 | .83 | 3.887 | .135 |
| | CG | 27 | 3.33 | .78 | 3.430 | .144 |
| Satisfaction | TG1 | 34 | 4.39 | .51 | 4.42 | .130 |
| | TG2 | 35 | 3.99 | .9 4 | 3.97 | .124 |
| | TG3 | 29 | 3.72 | .96 | 3.95 | .146 |
| | CG | 27 | 3.34 | .73 | 3.29 | .142 |

*Note.* Variation theory based GeoGebra problem-solving instructional approach (TG1); Variation theory based problem solving instructional approach (TG2), GeoGebra problem-solving instructional approach (TG3) and a comparison group (CG)

Table 6

*Analysis of Covariance for students' motivation and components of motivation in learning geometry as a Function of the Three Groups, Pre-test as a Covariate*

| *Variable* | *Source* | *df* | *Ms* | *F* | *p* | $\eta^2$ |
|---|---|---|---|---|---|---|
| Motivation | *Pre-test* | 1 | 9.213 | 41.359 | .000 | .261 |
| | Groups | 3 | 1.792 | 8.046 | .000 | .171 |
| | Error | 117 | .223 | | | |
| | *Pre-test* | 3 | 2.979 | 6.041 | .018 | .047 |
| Intrinsic value | Groups | 1 | 2.844 | 5.767 | .001 | .134 |
| | Error | 117 | .493 | | | |
| Self-efficacy | *Pre-test* | 1 | 3.231 | 6.440 | .012 | .052 |
| | Groups | 3 | 3.367 | 6.711 | .000 | .147 |
| | Error | 117 | .502 | | | |
| | *Pre-test* | 1 | 7.935 | 18.461 | .000 | .136 |
| Utility value | Groups | 3 | 1.461 | 3.399 | .020 | .080 |
| | Error | 117 | .430 | | | |
| | *Pre-test* | 1 | 13.354 | 27.485 | .000 | .190 |
| Test anxiety | Groups | 3 | 2.079 | 4.279 | .007 | .099 |
| | Error | 117 | .486 | | | |
| Extrinsic motivation | *Pre-test* | 1 | 12.742 | 20.169 | .000 | .147 |
| | Groups | 3 | 2.941 | 4.655 | .004 | .107 |
| | Error | 117 | .632 | | | |
| Attention | *Pre-test* | 1 | 6.472 | 12.320 | .001 | .095 |
| | Groups | 3 | 1.707 | 3.250 | .024 | .077 |
| | Error | 117 | .525 | | | |
| Satisfaction | *Pre-test* | 1 | 6.559 | 12.241 | .001 | .095 |
| | Groups | 3 | 2.760 | 5.151 | .002 | .117 |
| | Error | 117 | .536 | | | |

The above data shows that previous tests of overall motivation, intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation, attention and satisfaction of students in learning geometry had a significance effect on the posttest result since *p* value < .05.

As can be seen from Table 6, when the effect of the students' pre-motivation, pre-intrinsic motivation, pre-self-efficacy, pre-utility value, pre-test anxiety, pre-extrinsic motivation, pre-attention and pre-satisfaction were controlled, there were statistically significant differences between the three intervention and comparison groups in post-motivation ($F(3, 117) = 8.046$, $p < .05$, $\eta^2 = .171$), post-intrinsic motivation ($F(3, 117) = 5.7600$, $p < .05$, $\eta^2 = .134$), post-self-efficacy ($F(3, 117) = 6.711$, $p < 0.05$, $\eta^2 = .147$), post-utility value ($F(3, 117) = 3.399$, $p < .05$, $\eta^2 = .080$), post-test anxiety ($F(3, 117) = 4.279$, $p < .05$, $\eta^2 = .099$), post-extrinsic motivation ($F(3, 117) = 4.655$, $p < .05$, $\eta^2 = .107$), post-attention ($F(3, 117) = 3.25$, $p < .05$, $\eta^2 = .077$) and post-satisfaction ($F(3, 117) = 5.151$, $p < .05$, $\eta^2 = .117$).

In this study, for post motivation and post components of motivation the partial eta-squared indicate that all have small effect size according to (Cohen et al , 2010). Furthermore, the values of $\eta^2$ indicate that the instructional approaches were responsible for 17.1% of the variability in the post-motivation mean scores; 13.1% of the variability in the post- intrinsic motivation mean scores; 14.7% of the variability in the post- self-efficacy mean scores; 8% of the variability in the post- utility value mean scores; 9.9% of the variability in the post- test anxiety mean scores; 10.7% of the variability in the post- extrinsic motivation mean scores; 7.7% of the variability in the post-attention mean scores; and 11.7% of the variability in the post-satisfaction mean scores. These indicate that the teaching approaches used had a considerable effect on the groups' post-motivation, post- intrinsic motivation, post- self-efficacy, post- utility value, post- test anxiety, post- extrinsic motivation, post- attention, and post-satisfaction mean scores.

Therefore, from the above data we conclude that there is a significant difference between the groups in the post-test results when the pre-test results are controlled in the overall motivation, intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation, attention and satisfaction of students in learning geometry. But, it didn’t show which groups made significance differences. Therefore, Table 7 indicate among which group the difference exist keeping their pretest result as covariate on the motivational scales, then it is time to show between which group the difference exist.

Table 7

*The Bonferroni test based on the adjusted components of post-motivation and post-motivation components mean by Groups which had significant value*

| *Variable* | *(I) group* | *(J) group* | *Mean Difference (I-J)* | *p* |
|---|---|---|---|---|
| Post-intrinsic | TG1 | CG | 1.103* | <.001 |
| | | TG2 | .249 | .915 |
| | | TG3 | .491* | .049 |
| | TG2 | CG | .854* | <.001 |
| | | TG3 | .242 | 1.00 |
| | TG3 | CG | .612* | .011 |
| Post-self-efficacy | TG1 | CG | .974* | <.001 |
| | | TG2 | .232 | 1.00 |
| | | TG3 | .286 | .752 |
| | TG2 | CG | .742* | .001 |
| | | TG3 | .054 | 1.000 |
| | TG3 | CG | .688* | .003 |
| Post-utility | TG1 | CG | 1.058* | <.001 |
| | | TG2 | .391 | .093 |
| | | TG3 | .358 | .206 |
| | TG2 | CG | .667* | .001 |
| | | TG3 | −.033 | 1.00 |
| | TG3 | CG | .700* | .001 |
| Post-test anxiety | TG1 | CG | −.754* | .001 |
| | | TG2 | −.001 | 1.00 |
| | | TG3 | −.007 | 1.00 |
| | TG2 | CG | −.753* | <.001 |
| | | TG3 | −.006 | 1.00 |
| | TG3 | CG | .747* | .001 |

Table 7 continued

| *Variable* | *(I) group* | *(J) group* | *Mean Difference (I-J)* | *p* |
|---|---|---|---|---|
| Post-extrinsic motivation | TG1 | CG | 1.053* | <.001 |
| | | TG2 | .478 | .101 |
| | | TG3 | .323 | .767 |
| | TG2 | CG | .576* | .035 |
| | | TG3 | −.154 | 1.00 |
| | TG3 | CG | .730* | .007 |
| Post-attention | TG1 | CG | .938* | <.001 |
| | | TG2 | .292 | .672 |
| | | TG3 | .482 | .077 |
| | TG2 | CG | .646* | .005 |
| | | TG3 | .190 | 1.00 |
| | TG3 | CG | .456 | .133 |
| Post-satisfaction | TG1 | CG | 1.129* | <.001 |
| | | TG2 | .429 | .111 |
| | | TG3 | .465 | .114 |
| | TG2 | CG | .700* | .002 |
| | | TG3 | .036 | 1.00 |
| | TG3 | CG | .663* | .009 |
| Post-motivation | TG1 | CG | .776* | <.001 |
| | | TG2 | .313 | .055 |
| | | TG3 | .284 | .159 |
| | TG2 | CG | .463* | .001 |
| | | TG3 | −.029 | 1.00 |
| | TG3 | CG | .492* | .001 |

*Note.* *The mean difference is significant at the .05 level

Table 7 indicate that the adjusted post-test score results in the Bonferroni test show that whether or not there are significance mean differences on the post-intrinsic, post-self-efficacy, post utility value, post-test anxiety, post-extrinsic motivation, post-attention, post-satisfaction and post-overall motivation between the groups.

The result showed that Variation theory based GeoGebra problem-solving instructional approach; Variation theory based problem solving instructional approach, GeoGebra problem-solving instructional approach made significant differences with the comparison group for all post-motivation and post-components of motivation, except GeoGebra problem-solving instructional approach did not made significant difference with the comparison group. In addition, Variation theory based Geogebra problem-solving instructional approach made significant differences with Geogebra problem-solving instructional approach.

## 6. Discussion

The study's major focus was on how variation theory problem based approaches, GeoGebra problem based approaches and variation theory GeoGebra assisted problem based approaches improved students' motivation toward geometry learning. The results showed that students' over all motivation, which means that variation theory based GeoGebra problem-solving instructional approach; variation theory based problem-solving instructional approach, GeoGebra problem-solving instructional approach were brought a significant impact on students' motivation for learning geometry than the conventional method. Moreover, variation theory based GeoGebra problem-solving instructional approach (mixed approaches) contribute highest mean difference than the other two intervention groups such as variation theory based problem solving instructional approach, and GeoGebra problem-solving instructional approach on students' motivation. On the other hand GeoGebra problem-solving instructional approach contributes higher mean difference on student's motivation than variation theory based problem-solving instructional approach. The result shows that integrating technology with other approaches yield students to have good motivation towards learning geometry. These results are consistent with prior studies indicating that both variation theory-based approaches (Lo, 2012) and technology-supported problem-based instruction (Çakıroğlu & Öztürk, 2017) can significantly enhance students' motivation in learning mathematics and geometry. Integrating dynamic tools like GeoGebra with effective pedagogical approaches yields higher learning motivation (Boaler, 1998; Hattie & Yates, 2014). Dereje (2023) also showed that technology-supported inquiry-based approaches, such as the integration of dynamic geometry software, can positively influence students' conceptual understanding and motivation in geometry learning (Dereje, 2023).

Students under treatment groups’ (TG1, TG2 and TG3) had more intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation attention and satisfaction to learn geometry than the comparison group students. This meant that the treatment methods were significantly affect students’ intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation attention and satisfaction for learning geometry than the conventional method. Moreover, variation theory based GeoGebra problem-solving instructional approach contribute highest mean difference than the other two intervention groups such as variation theory based problem solving instructional approach, and GeoGebra problem-solving instructional approach on students’ intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation attention and satisfaction motivation. On the other hand GeoGebra problem-solving instructional approach contributes higher mean difference on student’s intrinsic motivation, self-efficacy, utility value, test anxiety, extrinsic motivation attention and satisfaction than variation theory based problem-solving instructional approach. This shows that integration of technology with other approaches contribute to students to have good for all components of motivation. This shows that students learning geometry with integrated instructional approaches were highly improved than the separate instructional approaches. These results are consistent with recent findings indicating that integrating technology such as GeoGebra with pedagogical frameworks like variation theory or inquiry-based learning significantly enhances various components of students’ motivation—including intrinsic motivation, self-efficacy, utility value, and satisfaction—when compared to traditional instruction (Dereje, 2023; Dereje & Drukpa, 2020).

In line with the above findings there are a lot of researches which were arrived similar results with respect to the effects of variation theory and GeoGebra on motivation in general. For example the above findings were consistent with other reported studies. For example, Jing et al. (2017) indicated that utilization of variation theory based instruction yields students to have higher motivation on attention and satisfaction. A multivariate analysis of variance was conducted to explore the impact of instructional strategy on students’ overall motivation and its subscales. The result indicated that there was a statistically effect of instructional strategy (group) on students’ Overall Motivation (Cheng, 2016; Jing et al., 2017). Furthermore some variation theory integrated with other instructional approaches significantly enhances Ethiopian grade ten students' Self-Belief in learning solid geometry. The observational evidence underpins the potential of this directions approach to address the determined instructive challenges in Ethiopia, especially in learning mathematics (Jing et al., 2017; Yeshanew et al., 2024).

Similarly, Shadaan and Eu (2013) study whereby it was observed that GeoGebra based activities encouraged higher order thinking skills, and had a positive effect in motivating students toward learning. Students enjoyed on learning mathematics much more when using GeoGebra and were able to form better connections between previous learning and new learning. However, some students reported they were not so confident when using the GeoGebra software.

Integrating GeoGebra with other instructional approaches yields better motivation in learning geometry. This finding coincides with Bache et al. (2024) GeoGebra supported learning with an integrated approach has higher inspiration and is more engaged in certain geometrical tasks than students uncovered to conventional paper-pencil instruction. These strategies energized the secondary school understudies to memorize the points by visualizing abstract geometrical concepts. Therefore, employing a collaborative approach integrated with GeoGebra might progress students motivation to memorize geometry relative to other directions strategies.

When the components of pre-motivation and pre-overall motivation were controlled, the results showed that groups taught using a variation theory based GeoGebra assisted problem solving approache had better overall motivation and its components toward learning geometry than those taught with a conventional instructional method. The findings of Lapinid and Mendoza (2024) also support the above results According to them, when students are more motivated then their problem solving skills increased. Using Variation Theory of learning as a pedagogical design tool is effective in improving the students' knowledge, procedural, and problem-solving skills since they are more motivated while they are learning using variation theory approaches. On the other hand the result of this study contradicted to (Wong et al., 2010) which found that students in Hong Kong (urban region) did not yield positive motivational reaction toward Variation theory based instruction treatment

The interview results also indicated an improvement in the students' post-motivation components and post-overall motivation on learning geometry. The rationale for the intervention group 3 students' better motivation toward learning geometry was due to the effective formation of the teaching approach through Variation theory based GeoGebra assisted problem solving teaching. This study's findings are consistent with those of (Ahlquist & Gynther, 2020) variation theory helps to engage on tasks in a constructive way. Furthermore Murni et al. (2017) who found that using GeoGebra-assisted problem-based learning can help students to solve problems and improve their attitudes toward mathematics. This idea is also supported by the results of the teacher interview protocol. Thus, it emphasizes the significance of adding structured variation theory and mixed instructional approach used in class. As a result, the integrated approaches can help students feel more liberated and positive about learning geometry.

Many researcher agree on that when a classroom instruction design with variation theory students are become more motivated and engaged on solving problems. This finding also supported by Jing et al. (2017) motivation will come when a lesson was desgne with variation theory context. Furthermore using mixed instruction of Variation theory Yeshanew et al., (2024) on their findings suggest that the integration of variation theory with Guided Inquiry-Based Instruction effectively enhances students motivation in self-beliefs in learning solid geometry, thereby addressing the educational challenges faced by Ethiopian students.

In general, the favorable outcomes of variation theory and GeoGebra assisted problem-based learning could be directly attributed to the study's instructional methods. Starting each session with an aspect of variation theory, Phases of variation theory based GeoGebra assisted problem solving approaches, and Phases of GeoGebra-assisted problem solving approaches, the instructional approaches in each of the intervention groups encouraged the students to examine the existing knowledge that they had in their minds. The significance of geometrical concepts to what the students are familiar with is emphasized in each of the intervention groups, which encourages students to learn geometry.

Depending on the content of the instructions, students in all intervention groups engaged with attending in a motivated way through frequent engagement with their classmates. As a result, rather than receiving the concepts inertly, they had the opportunity to explore the concepts of geometry, as well as the relationships between the concepts of geometry. All of these events are designed to boost students' interest in geometry, as well as their motivation toward learning geometry.

The results of the teacher interviews also revealed that students' motivation toward geometry had improved. The use of variation theory based GeoGebra assisted problem solving approaches, variation theory problem solving approaches and GeoGebra assisted problem solving approaches, could have made the importance of learning geometry to students more explicit. It could also have enhanced students' motivation components toward learning geometry and motivated them to learn more, allowing them to excel in the topic. The intervention group students' motivation and components of motivation were improved, and the variation theory and GeoGebra problem solving approaches separately and in mixed instructions were applied, according to the teachers who taught the three intervention groups. As a result, students appear to like geometry more since they have the ability to learn realistically by applying it to their daily lives.

## 7. Conclusion and Recommendations

The study explored the effect of a variation theory-based GeoGebra-assisted instructional approach on 9th grade students' motivation in learning geometry. The results indicated a statistically significant difference between the mean scores of pre- and post-motivation within the intervention group, suggesting a positive impact of the instructional method. In contrast, no significant difference was found in the comparison group. Additionally, when controlling for pre-motivation and its subscales, a significant difference emerged between the post-motivation scores of the two groups. These findings suggest that the variation theory-based GeoGebra-assisted instruction effectively enhanced students' motivation in learning geometry, both in general and across specific subscales. The integration of GeoGebra and variation theory was found to be a beneficial instructional approach, supporting improved student engagement and motivation in geometry learning.

Based on the conclusions and the deviant results obtained in this study, the following recommendations are forwarded: Teachers should be encouraged and supported to implement variation theory-based GeoGebra-assisted problem-solving approaches to enhance students' understanding and motivation in geometry. School administrations should prioritize the integration of GeoGebra software by equipping IT labs and ensuring access to necessary technological resources. Additionally, government officials and educational policymakers should recognize and promote the implementation of technology in schools as aligned with curriculum goals, supporting initiatives that foster technology-enhanced learning environments.

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**Data availability:** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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