International Journal of Secondary Education
2024, Vol. 12, No. 3, pp. 56-67
https://doi.org/10.11648/j.ijsedu.20241203.12

Research Article

Effects of Variation Theory Integrated Guided Inquiry-Based Instruction on Grade Ten Students Self-Belief in Learning Solid Geometry

Abebaw Yeshanew[1,*], Tesfu Belachew[2], Habtamu Gezahegn[3], Tadele Tesfa[1]

[1]Mathematics, Hawassa University, Hawassa, Ethiopia
[2]Mathematics, Meda Wolabu University, Bale, Ethiopia
[3]Educational Planning and Management, Hawassa University, Hawassa, Ethiopia

Abstract

In mathematics education, students' beliefs that could take many different forms like students' beliefs about mathematics learning mathematics teaching; and about themselves play a significant role in their learning and achievement. In particular, self-belief (SB) that is students' evaluation and judgment about themselves in learning solid geometry, which encompassing control belief (CB), goal orientation (GO), self-concept (SC), self-efficacy (SE), and task value (TV), is critical to their success in learning solid geometry. Addressing these SB dimensions can substantially improve students' learning outcomes in solid geometry. Innovative, student-centered instructional approaches like GIBI, especially when combined with variation theory, offer a potential solution for overcoming Ethiopian secondary schools' educational challenges by promoting active learning and providing varied examples to enhance engagement and achievement. However, there is a lack of research on the effectiveness of this combined approach in Ethiopia context. This study aims to fill this gap by investigating the effects of variation theory integrated GIBI on grade ten students' SB in learning solid geometry in Ethiopia. Employing a quasi-experimental with non-equivalent control group pretest-posttest design, 102 students from three public secondary schools in Debre Tabor city, Amhara region were randomly assigned into three groups: Experimental Group 1 (EG1) received GIBI with variation theory, Experimental Group 2 (EG2) received GIBI without variation theory, and the Control Group (CG) received traditional teaching methods. A SB questionnaire was used to measure students' CB, GO, SC, SE, and TV before and after the intervention. The results revealed significant improvements in the SB dimensions among students in EG1 compared to those in EG2 and CG. Specifically, EG1 students showed higher post-test scores in CB ($F(2,99)=40.29$, $p=0.000$, $\eta^2=0.449$); GO ($F(2,99)=3.43$, $p=0.036$, $\eta^2=0.065$); SC ($F(2,99)=32.09$, $p=0.000$, $\eta^2=0.393$); SE ($F(2,99)=24.02$, $p=0.000$, $\eta^2=0.327$); and TV ($F(2,99)=5.35$, $p=0.000$, $\eta^2=0.097$). Tukey post hoc tests indicated that EG1 students' scores were significantly higher than those of the CG in CB and GO, and higher than EG2 and CG in SC, SE, and TV. These findings suggest that the integration of variation theory with GIBI effectively enhances students' SB in learning solid geometry, thereby addressing the educational challenges faced by Ethiopian students. The study recommends adopting this instructional approach more widely to improve student outcomes in mathematics.

Keywords

Guided Inquiry-Based Instruction, Self-Belief, Solid Geometry, Variation Theory

[*]Corresponding author: y.abebaw2012@gmail.com (Abebaw Yeshanew)

Received: 7 August 2024; **Accepted:** 3 September 2024; **Published:** 20 September 2024

1. Introduction

The teaching and learning of solid geometry, which involves the study of three-dimensional objects like cubes and spheres [1] is one of the most important branches of mathematics [2]. Geometry affords students experiences that resemble the work of mathematicians, helps them interpret and systematize their intuition about the world, and allows practical connections to the real-world skills students will need in their future working lives [3]. Due to this, geometry has a very significant place in mathematics education [4]. This subject is fundamental for advanced fields such as engineering and physics but often poses difficulties for students due to its abstract nature and the spatial visualization skills required [5]. These challenges are particularly pronounced in Ethiopian secondary schools, where traditional teaching methods predominate [6-8], leading to low student engagement, poor performance in mathematics, and negative self-belief.

Self-belief (SB), encompassing control belief, goal orientation, self-concept, self-efficacy, and task value, is critical to students' success in learning solid geometry. Control belief is the confidence that effort will lead to success, and goal orientation-whether mastery or performance-based-affects engagement and achievement. Research indicates that emphasizing mastery goals and fostering a positive self-concept enhances students' performance in mathematics [9, 10]. Self-efficacy, or the belief in one's ability to succeed, is a strong predictor of better performance in math [11]. Additionally, the perceived task value, which reflects the importance and usefulness of geometry tasks, significantly boosts motivation and achievement [2].

Addressing these dimensions of self-belief can substantially improve students' learning outcomes in solid geometry. Innovative teaching methods that enhance SB are crucial for overcoming educational challenges, particularly in Ethiopian secondary schools. Implementing such methods can help students build confidence, engage more deeply with the material, and ultimately achieve better academic results. Guided Inquiry-Based Instruction (GIBI) has emerged as a promising approach to address these issues. By actively engaging students through exploration and inquiry [12]. Incorporating variation theory into GIBI further enhances learning by providing diverse examples, facilitating deeper comprehension and application of abstract concepts [13, 14] and improving students' motivation [15].

Despite the potential of both GIBI and variation theory, there is limited empirical evidence on their combined effects on students' SB in learning solid geometry globally, particularly in Ethiopia context. Thus, this study aims to fill this gap by investigating the effects of variation theory integrated GIBI on grade ten students' SB in learning solid geometry in Amhara region, Ethiopia. Besides, the findings of this study would have the potential to contribute significantly to educational improvement efforts and inform future instructional practices in Ethiopia and similar contexts globally.

1.1. Statement of the Problem

Ethiopia's educational system has undergone significant reforms over the past few decades, aimed at improving the quality of education. However, despite these efforts, challenges persist, particularly in the areas of mathematics [16]. Ethiopian students often struggle with geometry, a critical component of the mathematics curriculum, which has implications for their overall academic achievement and future career opportunities in STEM fields [17]. Students often have low engagement, poor performance, and negative self-beliefs about their mathematical abilities, exacerbated by limited resources and infrastructure [18]; large class sizes and high teaching loads [7]; predominant lecture-based teaching methods [7, 8]; and students' negative self-belief and motivation to learn [19-22].

Traditional instruction methods, which focus on rote learning and teacher-centered approaches, fail to foster students' SB and motivation [6]. Innovative, student-centered instructional approaches like GIBI, especially when combined with variation theory, offer a potential solution by promoting active learning and providing varied examples to enhance engagement and achievement [14]. However, there is a lack of research on the effectiveness of this combined approach in Ethiopia. This study aims to fill this gap by investigating the effects of GIBI using variation theory on grade ten students' self-belief in learning solid geometry in Ethiopia.

1.2. Research Objectives

The study aimed to explore the effects of the integration of variation theory and GIBI on grade ten students' SB in learning solid geometry. Specifically, it investigated the effects of this instructional strategy on their Control Belief (CB), Goal Orientation (GO), Self-Concept (SC), Self-Efficacy (SE), and Task Value (TV).

1.3. Research Questions

1. Is there a significant difference in students' SB in learning solid geometry between the experimental and the control groups?
2. Is there a significant difference in students' CB, GO, SC, SE, and TV in learning solid geometry between the experimental and the control groups?

2. Literature Review

2.1. Self-Belief and Learning Geometry

Self-belief refers to students' evaluations and judgments about their ability to learn solid geometry [23]. It encompasses control belief, goal orientations, self-concept, self-efficacy, and task value, all of which are crucial for academic success and motivation in mathematics.

2.1.1. Control Belief

Control belief is students' perception that their efforts to learn geometry will result in positive outcomes [24, 25] said that efforts should be enhanced to raise the academic self-concept of students, which will in turn boost their confidence in mathematics and thus improve grades. Active participation and problem-solving also foster an internal locus of control, reinforcing students' belief in their ability to influence learning outcomes. Empirical evidence supports this [9] found that students with high mathematics self-efficacy (as measured as beliefs of effort, and persistence) perform better in mathematical tests than those with medium or low self-efficacy.

2.1.2. Goal Orientation

Goal orientation refers to students' reasons for engaging in learning activities and includes mastery goals, performance approach, and performance-avoidance goals. Emphasizing mastery orientation promotes deeper engagement with solid geometry. Studies, such as those by [10, 26], show that mastery goals positively impact mathematics achievement and engagement. Creating a mastery-oriented classroom environment is thus essential for fostering students' mastery goals [27].

2.1.3. Self-Concept

Mathematical self-concept is students' self-perception of their academic abilities in mathematics [28]. It affects students' engagement with mathematics in the short and long term [29]. Lack of confidence makes the students tense during tests and examinations [30] and they will develop long-lasting negative attitudes toward mathematics [31]. Whereas, a positive self-concept influences the effort students exert in school tasks, thereby enhancing performance [32]. Research, including studies by [33, 34], shows that a strong academic self-concept significantly predicts mathematics achievement. Boosting students' self-concept through positive feedback and a supportive learning environment is crucial [29, 35].

2.1.4. Self-Efficacy

Self-efficacy is students' belief in their ability to perform specific tasks successfully [36]. It is a well-researched predictor of students' learning and achievement. Studies by [11] and [37] demonstrate a strong positive relationship between self-efficacy and geometry test scores. [38] also found significant pathways from academic self-efficacy to math achievement. However, [39] found no relationship between prior self-efficacy and later math grades in German students.

2.1.5. Task Value

Task value is students' perceived intrinsic, utility, and attainment value of geometry tasks [28, 40]. Studies by [2, 41] show that high task value correlates with better learning and achievement. Similarly [42] found that students' instrumental motivation significant predictor of their mathematics achievement. When students intrinsically value mathematics, they are more likely to deeply engage in mathematics activities and be more resilient in the face of difficulty while doing mathematics thinking [43]. To improve students' performance in geometry [30] argued that students should perceive mathematics as being important, and relevant. Positive emotions and intrinsic value derived from engaging, real-world applications of solid geometry motivate students to learn and improve their performance [44].

In conclusion, empirical evidence indicates that SB dimensions are vital for improving students' learning and achievement in mathematics, particularly solid geometry. To address Ethiopian secondary school students' learning difficulties and low achievement in solid geometry, innovative teaching methods, like GIBI and variation theory, that foster these SB dimensions should be implemented.

2.2. Guided Inquiry-Based Instruction

Guided Inquiry-Based Instruction (GIBI) is a student-centered approach that promotes active experimentation and independent problem-solving, helping students build on prior knowledge and engage their creativity [12, 45]. Research shows that GIBI enhances various dimensions of students' self-belief, such as control beliefs, goal orientation, self-efficacy, and task value [46-48].

2.3. Variation Theory and Learning Geometry

Marton's variation learning theory postulates that meaningful learning is achieved when students are exposed to variations in critical aspects of a concept, enabling them to discern key features and relationships. It helps students identify and understand essential elements of the subject matter, enhancing their ability to apply knowledge in novel situations. It also emphasizes exposing students to varied aspects of a concept, facilitating deeper understanding and abstraction [49]. In the context of solid geometry, this theory suggests that by varying dimensions, orientations, and properties of geometric solids, students can develop a more nuanced understanding of spatial relationships and improve their problem-solving skills [13]. For instance, when students engage with different versions of a geometric solid, where specific attributes like height or volume are systematically altered, they are better able to focus on how these changes affect the overall properties of the shape.

Teaching and learning through variation have been practiced for centuries in China. Gu and his colleagues have explored how to use and theorize teaching through variation "Bianshi Teaching" to increase student achievement in mathematics since the 1980s and enhances students' grasp of solid geometry by systematically using both conceptual and procedural patterns of variation to focus on critical features of geometric concepts [50]. Conceptual patterns involve altering fundamental ideas, such as presenting different geometric solids (e.g., cubes, pyramids) to emphasize distinct properties like volume and surface area. The teacher provides examples of a concept by offering deliberately varied representations (i.e. Conceptual variation) contributing to a deeper understanding of a concept. The idea of Gu's procedural variation can be summarized as the means to 'progressively unfold the mathematical activities', which can be achieved by expanding problem-solving activities to include: variation on the problem; different solutions to a problem, and one solution applied to different problems [51].

Studies have demonstrated that the combination of Matron's variation theory and Gu's teaching through variation enhances higher-order thinking, academic performance, and students' motivation [15, 52, 53]. Moreover, research shows that integrating variation theory with constructivist approaches like GIBI improves mathematical understanding and achievement [14, 54].

The integration of variation theory and GIBI also positively affects students' SB. GIBI fosters active learning and inquiry, boosting students' self-concept and task value, while Variation Theory's varied examples help them appreciate the relevance of mathematical concepts [55]. Evidence suggests that this combined approach improves self-efficacy and control belief, addressing both cognitive and affective dimensions of learning [46, 56].

From the above empirical evidence, we concluded integrating GIBI with variation theory presents a promising solution for Ethiopian students who are struggling with geometry. Despite the potential benefits, there is limited research on the effects of GIBI and variation theory specifically in the context of geometry learning. This study aims to explore how integrating these methods affects tenth-grade students' SB in learning solid geometry, contributing valuable insights to educational strategies in Ethiopia and beyond.

3. Materials and Methods

A quasi-experimental with a non-equivalent control group pretest-posttest design was utilized to examine the effects of variation theory integrated GIBI on grade ten students' SB dimensions (CB, GO, SC, SE, and TV) in learning solid geometry. Table 1 below shows the design of the study.

Table 1. *Research Design Layout.*

Study Groups		Intervention	
EG1	Pre-Test	GIBI plus Variation Theory	Post-Test
EG2	Pre-Test	GIBI	Post-Test
CG	Pre-Test	Traditional Teaching Methods	Post-Test

Note: EG1: Experimental Group 1; EG2: Experimental Group 2; and CG: Control Group

As shown in (see Table 1), EG1 was taught by GIBI using variation theory; EG2 was instructed by GIBI only; and the CG passed through traditional teaching methods. We used CG for compaction purposes only. All three study groups were pre-tested before the intervention to check their baseline on SB in learning solid geometry. After the interventions, all groups were post-tested using the same questionnaire with some reshuffling of its items.

A multi-stage sampling was used to select research participants. First, using purposively sampling that took their infrastructures, the profile of mathematics teachers, and average class size into account, three public secondary schools from Debre Tabor city, Amhara region, Ethiopia were selected, and then from each school three mathematics teachers were included as participants using purposive sampling by taking their educational level, and teaching experience into consideration.. Finally, three grade ten classes (one from the selected mathematics teacher's intact classes) were randomly chosen and assigned as experimental and control groups. The total participants of the study were 102 grade ten students. Their distribution was: EG1 (n=31), which was taught with GIBI using variation theory; EG2 (n=39), which received GIBI; and CG (n=32), which passed through traditional teaching methods.

We used the SB questionnaire to assess the students' SB in learning solid geometry both before and after the intervention. It contains nine demographic questions and 36 items with a points Likert scale (1=strongly disagree, 2=disagree, 3=undecided, 4=agree, and 5=strongly agree) that was adapted from previously used valid questionnaires. These items are grouped into five SB dimensions: five items for control belief; eight items for achievement goals orientations; seven items for mathematics self-concept; four items for self-efficacy, and 12 items for task value.

The face and content validity of the questionnaire was ensured by advisors and two lecturers from the Begemidir College of Teacher Education psychology department. The Amharic version of the questionnaire was piloted a month ago before the intervention with a sample of 39 (10 males and 29 females) grade ten students of Debre Tabor Secondary School who weren't part of the study to determine its reliability. The calculated Cronbach Alpha of the questionnaire was 0.925. Besides, Table 2 below shows the Cronbach alpha values of SB dimensions.

Table 2. *Reliability Test Result.*

SB Dimensions	Cronbach Alpha
Control Belief (CB)	0.704
Goal Orientation (GO)	0.752
Self-Concept (SC)	0.786
Self-Efficacy (SE)	0.676

SB Dimensions	Cronbach Alpha
Task Value (TV)	0.777

Data collection involved administering the SB questionnaire as pretests before the intervention and as posttests after the intervention. During the administration of the pre-test, 104 students filled out the SB questionnaire. However, after the intervention, only 102 students filled out the questionnaire. The intervention lasted for four weeks, with the EG1 receiving instruction with GIBI plus variation theory, EG2 was taught using GIBI, while the CG passed through traditional teaching methods.

Descriptive statistics (mean and standard deviation) were used to summarize the pre-test and post-test scores of students' SB, CB, GO, SC, SE, and TV data, and an inferential statistic like ANOVA and MANOVA were used to compare the study groups' SB and its dimensions pre-test and post-test scores respectively. All analysis was executed using SPSS version 24 software.

4. Results

Research Question 1. Is there a significant difference in students' SB in learning solid geometry between the experimental and the control groups?

To answer this research question, we have computed ANOVA to check whether or not the study groups statistically differ in their SB before the intervention. Before executing ANOVA, we performed a preliminary analysis of its assumptions. The results showed that all assumptions weren't violated. Table 3 below shows the ANOVA results.

Table 3. *ANOVA result of SBPreTS.*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1112.230	2	556.115	1.982	.143
Within Groups	28344.530	101	280.639		
Total	29456.760	103			

Note: SBPreTS: Self-belief pre-test scores

Based on Table 3, there was no significant difference (F (2, 101) =1.98, p=0.143) across study groups in their SB before the intervention. So, ANOVA was utilized to compare the study groups' mean scores in their SB posttest and answer the first research question stated above.

Table 4. *ANOVA result of SBPostTS.*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9422.118	2	4711.059	27.269	.000
Within Groups	17103.343	99	172.761		
Total	26525.461	101			

Note: SBPostTS: Self-belief post-test scores

Based on the results in Table 4, a significant difference was found (F (2,99) =27.26, p=0.000) across the study groups in their SBPostTS. To determine the nature of this difference, further analysis is needed. So, we executed Tukey Post Hoc tests (see Table 5).

Table 5. *Post Hoc Tests for SBPostTS.*

	(I) Study Groups	(J) Study Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	EG1	EG2	16.001	3.163	.000	8.48	23.53
		CG	24.004	3.312	.000	16.12	31.89
	EG2	EG1	-16.001	3.163	.000	-23.53	-8.48
		CG	8.003	3.135	.032	.54	15.46
	CG	EG1	-24.004	3.312	.000	-31.89	-16.12
		EG2	-8.003	3.135	.032	-15.46	-.54

The results in Table 5 above, a significant difference was found among the study groups. EG1 which taught with GIBI using variation theory scored high in their SB (Mean=131.13, SD=10.356) when compared with EG2 which received GIBI only (Mean=116.13, SD=15.143), and CG that passed through traditional teaching methods (Mean=108.13, SD=12.916) as shown in Table 6 below. Besides, a significant difference was found between EG2 and CB in favor of EG2.

Table 6. *Descriptivist statistics for SBPostTS.*

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
EG1	31	132.13	10.356	1.860	128.33	135.93
EG2	39	116.13	15.143	2.425	111.22	121.04
CG	32	108.13	12.916	2.283	103.47	112.78
Total	102	118.48	16.206	1.605	115.30	121.66

We have computed MANOVA to check the study groups' baseline in their SB dimensions before the intervention. We have also checked all its assumptions weren't violated (see Table 7).

Table 7. *MANOVA for SB Dimensions PreTS.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Groups	CBPreTS	5.080	2	2.540	.370	.692	.007
	GOPreTS	149.699	2	74.850	2.919	.059	.055
	SCPreTS	174.711	2	87.355	4.359	.051	.079
	SEPreTS	20.999	2	10.500	1.333	.268	.026
	TVPreTS	61.781	2	30.891	.938	.395	.018
Error	CBPreTS	693.833	101	6.870			
	GOPreTS	2589.647	101	25.640			
	SCPreTS	2024.126	101	20.041			

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
	SEPreTS	795.761	101	7.879			
	TVPreTS	3325.209	101	32.923			
Total	CBPreTS	21167.000	104				
	GOPreTS	82604.000	104				
	SCPreTS	42175.000	104				
	SEPreTS	13291.000	104				
	TVPreTS	129043.000	104				

Note: CBPreTS: CB pre-test score; GOPreTS: GO pre-test score; SCPreTS: SC pre-test score; SEPreTS: SE pre-test score; and TVPreTS: TV pre-test score

As shown in Table 7. The study groups didn't statistically differ in their five SB dimensions before the intervention. Therefore, we executed MANOVA to compare the study groups' mean scores in their CB, GO, SC, SE, and TV.

Research Question 2. Is there a significant difference in students' CB, GO, SC, SE, and TV in learning solid geometry between the experimental and the control groups?

Table 8. *MANOVA for SB Dimensions PostTS.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	CBPostTS	751.183	2	375.591	40.290	.000	.449
	GOPostTS	198.248	2	99.124	3.427	.036	.065
	SCPostTS	611.734	2	305.867	32.089	.000	.393
	SEPostTS	206.212	2	103.106	24.015	.000	.327
	TVPostTS	243.506	2	121.753	5.345	.006	.097
Intercept	CBPostTS	25029.569	1	25029.569	2684.921	.000	.964
	GOPostTS	81489.363	1	81489.363	2817.003	.000	.966
	SCPostTS	44934.147	1	44934.147	4714.179	.000	.979
	SEPostTS	21093.959	1	21093.959	4913.156	.000	.980
	TVPostTS	151771.322	1	151771.322	6662.655	.000	.985
Groups	CBPostTS	751.183	2	375.591	40.290	.000	.449
	GOPostTS	198.248	2	99.124	3.427	.036	.065
	SCPostTS	611.734	2	305.867	32.089	.000	.393
	SEPostTS	206.212	2	103.106	24.015	.000	.327
	TVPostTS	243.506	2	121.753	5.345	.006	.097
Error	CBPostTS	922.905	99	9.322			
	GOPostTS	2863.840	99	28.928			
	SCPostTS	943.639	99	9.532			
	SEPostTS	425.043	99	4.293			
	TVPostTS	2255.161	99	22.779			
Total	CBPostTS	26553.000	102				

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
	GOPostTS	85229.000	102				
	SCPostTS	46874.000	102				
	SEPostTS	21932.000	102				
	TVPostTS	155000.000	102				

Note: CBPreTS: CB post-test score; GOPreTS: GO post-test score; SCPreTS: SC post-test score; SEPreTS: SE post-test score; and TVPreTS: TV post-test score

As we can see from Table 8 above, a significant difference was found across the study groups in their CBPostTS (F (2,99)=40.29, p=0.000, Partial Eta Squared (η^2)=0.449); GOPostTS (F (2,99)=3.43, p=0.036, η^2=0.065); SCPostTS (F (2,99)=32.09, p=0.000, η^2 =0.393); SEPostTS (F (2,99)=24.02, p=0.000, η^2 = 0.327); and TVPostTS (F (2,99)=5.35, p=0.000, η^2= 0.097).

Based on these findings, we have conducted Tukey post hoc tests to determine the nature of these differences among the three study groups. See Table 9 below.

Table 9. *Tukey HSD Post Hoc Tests of SB dimensions.*

Dependent Variable	(I) Study Groups	(J) Study Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
CBPostTS	EG1	EG2	5.21	.735	.000	3.46	6.96
		CG	6.49	.769	.000	4.66	8.32
	EG2	EG1	-5.21	.735	.000	-6.96	-3.46
		CG	1.28	.728	.189	-.45	3.01
GOPostTS	EG1	EG2	2.00	1.294	.274	-1.08	5.08
		CG	3.54	1.355	.028	.31	6.76
	EG2	EG1	-2.00	1.294	.274	-5.08	1.08
		CG	1.54	1.283	.457	-1.51	4.59
SCPostTS	EG1	EG2	2.87	.743	.001	1.10	4.64
		CG	6.22	.778	.000	4.37	8.07
	EG2	EG1	-2.87	.743	.001	-4.64	-1.10
		CG	3.35	.736	.000	1.60	5.10
SEPostTS	EG1	EG2	1.52	.499	.008	.33	2.71
		CG	3.60	.522	.000	2.36	4.84
	EG2	EG1	-1.52	.499	.008	-2.71	-.33
		CG	2.08	.494	.000	.90	3.25
TVPostTS	EG1	EG2	3.46	1.148	.009	.73	6.19
		CG	3.22	1.203	.023	.36	6.08
	EG2	EG1	-3.46	1.148	.009	-6.19	-.73
		CG	-.24	1.138	.975	-2.95	2.47

As shown in Table 9, EG1 scored high in their CBPostT and TVPostT when compared with EG2 and CG. Whereas, a significant difference wasn't found between EG2 and CG in their CBPostTS (p=0.189), and TVPostTS (p=0.975). Concerning SCPostTS and SEPostTS, EG1 scored high when compared with EG2 and CG. Similarly, the SCPostTS and SEPostTS mean values of EG2 were greater than that of CG. Finally, a significant difference was found only between EG1 and CG in their GOPostTS (p=0.028).

5. Discussion

The purpose of this was to investigate the effects of variation theory integrated Guided Inquiry-Based Instruction (GIBI) on grade ten student's self-belief (SB) in learning solid geometry in Ethiopia. Accordingly, two research questions were formulated.

The first research question is about comparing the mean scores of the study groups in their SB posttest. The students' SB was the linear combination of its dimensions (i.e. control belief (CB), goal orientation (GO), self-concept (SC), self-efficacy (SE), and task value (TV)). The ANOVA result showed that a significant difference was found across the study groups in their SBPostTS at a 95% confidence interval. (see Table 4). Based on the Tukey Post Hoc test result indicated that students in the experimental group that received GIBI with variation theory (EG1) showed substantial improvements in their SB compared to those that received GIBI (EG2) and that was taught by traditional teaching method (CG). Besides, the EG2 students' SB mean score was greater than that of CG students. These findings revealed that both the GIBI integrated with variation theory and GIBI effectively improved grade ten students' SB in learning solid geometry when compared with traditional teaching methods. However, the effects of GIBI integrated with variation theory were higher than GIBI and traditional teaching methods (see Table 5).

When we see the second research question, the MANOVA results a significant post-test scores difference was found across the study groups in their CB with Partial Eta Squared (η^2)=0.449; GO with η^2=0.065; SC with η^2=0.393; SE with η^2= 0.327); and TV with η^2= 0.097 (see Table 8). These implied 9.7% to 44.9% variation in students' SB dimensions was attributed to the intervention. These findings highlight the significant effects of variation theory integrated GIBI on the SB dimensions of grade ten students in learning solid geometry.

Our Tukey Post Hoc Tests results indicated that EG1 students' scores were significantly higher than those of the CG in CB and GO, and higher than both EG2 and CG in SC, SE, and TV. These findings suggest that the integration of variation theory with GIBI effectively enhances grade ten students' SB in learning solid geometry (see Table 9). Besides, EG2 students scored high in their SC and SE when compared with CG students. These findings are in line with the findings of [46, 48, 57, 58]. However, a significant difference wasn't found in students' CB, GO, and TV between EG2 and CG. These findings contradict the previous study findings that highlight the potential of GIBI in improving students' CB [46]; GO [47]; and TV [56, 59].

The significant differences observed in the SB dimensions between EG1 and the CG emphasize the effectiveness of the integration of variation theory and GIBI in enhancing students' beliefs in their capabilities. Specifically, EG1 students' post-test scores were significantly higher in CB, SC, SE, and TV, indicating that this instructional approach positively influences students' confidence and motivation in learning mathematics This is in line with the findings of [15] who found the effect of variation theory-based strategy on students' attention, relevance, confidence, and satisfaction over traditional teaching method. The lack of significant difference between EG2 and CG in CB, GO, and TV suggests that the addition of variation theory to GIBI is crucial for achieving these improvements.

Moreover, the significant differences in SC and SE between EG1 and both EG2 and CG further emphasize the role of variation theory in fostering both SC and SE among students. These findings align with previous research indicating that variation theory can enhance students' engagement [60].

6. Conclusions

This study demonstrates that variation theory integrated GIBI significantly enhances Ethiopian grade ten students' SB in learning solid geometry. The empirical evidence supports the potential of this instructional approach to address the persistent educational challenges in Ethiopia, particularly in mathematics education. By fostering students' SB, GIBI with variation theory can lead to improved engagement, persistence, and academic achievement in solid geometry.

The study fills a critical gap in the literature by providing insights into the effects of this innovative teaching method on students' SB in learning solid geometry in the Ethiopian context. The findings contribute to the global understanding of how GIBI with variation theory can be adapted and implemented in diverse educational settings to enhance students' SB in learning mathematics.

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

Educational institutions in Ethiopia and similar contexts should consider adopting GIBI with variation theory to improve students' self-belief in learning solid geometry and other challenging subjects.

Training programs should be developed to equip mathematics teachers with the skills and knowledge required to effectively implement GIBI and variation theory in their classrooms. The essentiality of such kind of training is also underlined by [61]. Because it can help in creating a more engaging and supportive learning environment for students.

Additional studies should be conducted to explore the long-term effects of the integration of variation theory and GIBI on students' self-belief in various subjects and educational levels. This can provide a more comprehensive understanding of the benefits and potential challenges of this instructional approach. Besides, future studies should utilize mixed research design that would help the scientific community to have a vivid understand how GIBI using variation theory enhanced students’ SB dimensions.

Abbreviations

CB	Control Belief
GIBI	Guided Inquiry-Based Instruction
GO	Goal Orientation
SB	Self-Belief
SC	Self-Concept
SE	Self-Efficacy
TV	Task Value

Author Contributions

Abebaw Yeshanew: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – original draft, Writing – review & editing

Tesfu Belachew: Methodology, Resources, Supervision, Validation, Writing – review & editing

Habtamu Gezahegn: Methodology, Supervision, Validation, Writing – review & editing

Tadele Tesfa: Methodology, Supervision, Writing – review & editing

Funding

This work is not supported by any external funding.

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Frederick-Jonah, T. M., Olotu, A. R., Egberifa, T. K. Areas and Reasons for Students' Difficulties in Learning Geometry by Gender in Senior Secondary School Mathematics Curriculum. International Journal of Research in Education and Sustainable Development. 2022, 2(6), 55-65. www.ijaar.org/ijresd

[2] Tsao, Y., Tung, W. High School Students’ Attitude Towards Their Learning Geometry. US-China Education Review. 2022, 12(3), 77-84. https://doi.org/10.17265/2161-623X/2022.03.001

[3] Herbst, P., Fujita, T., Halverscheid, S., Weiss, M. The Learning and Teaching of Geometry in Secondary Schools: A modeling perspective. Routledge; 2017.

[4] Serin, H. Perspectives on the Teaching of Geometry: Teaching and Learning Methods. Journal of Education and Training. 2018, 5(1), 130-137. https://doi.org/10.5296/jet.v5i1.12115

[5] Jones, K. Re-imagining geometry education in schools. In Beiträge zum mathematikunterricht 2020 auf der 54. Jahrestagung der Gesellschaft fur Didaktik der Mathematik (GDM) H-S. Siller, W. Weigel, and J. Franz Wörler, Eds., Münster: WTM-Verlag; 2020, pp. 31-38.

[6] Fabiyi, T. R. Geometry Concepts in Mathematics Perceived Difficult to Learn by Senior Secondary School Students in Ekiti State, Nigeria. IOSR Journal of Research & Method in Education (IOSR-JRME). 2017, 7(1), 83-90. www.iosrjournals.org

[7] Getinet, S. W. The actual status of general secondary school mathematics teaching and learning: The case of Ethiopia. Journal of Physics: Conf. Series 1176(2019) 042097. IOP Publishing. http://dx.doi.org/10.1088/1742-6596/1176/4/042097

[8] Yeshitila, M., Mamo, T. Factor Affecting Student`s Achievement in Mathematics: The Case of Agarfa Secondary School, Ethiopia. Education Journal. 2019, 8(6), 307-319. https://doi.org/10.11648/j.edu.20190806.21

[9] Arifin, S., Wahyudin, Herman, T. The Effect of Students’ Mathematics Self-efficacy on Mathematical Understanding Performance. Ilkogretim Online - Elementary Education Online. 2021, 20(1), 617-627. https://doi.org/10.17051/ilkonline.2021.01.52

[10] Guo, M., Leung, F. Achievement goal orientations, learning strategies, and mathematics achievement: A comparison of Chinese Miao and Han students. Psychol Schs.. 2020, 1–17. Wiley Periodicals LLC. https://doi.org/10.1002/pits.22424

[11] Agormor, S., Apawu, J., Aboagye-Agbi, J. J., Hokor, E. K. Prior mathematics achievement and mathematics self-efficacy as indicators for success in pre-service teachers’ achievement in geometry and trigonometry. Journal of Research in Instructional. 2022, 2(2), 115–128. https://doi.org/10.30862/jri.v2i2.83

[12] Jumantini, E., Satriapradja, N., Rahmat, P. S., Amalia, G. The Effect of Guided Discovery Learning Method and Guided Inquiry Learning in Improving Students Critical Thinking Ability with Students' Self-Effication Variable Moderator. UNISET. 2021, December 02, Kuningan, Indonesia. https://doi.org/10.4108/eai.2-12-2021.2320305

[13] Jacques, L. What is teaching with variation and is it relevant to teaching and learning mathematics in England? In Research proceedings of the 9th British Congress on mathematics education. J. Golding, N. Bretscher, C. Crisan, E. Geraniou, J. Hodgen, and C. Morgan. Eds. University of Warwick, UK; 2018. https://www.bsrlm.org.uk/bcme-9/

[14] Voon, X. P., Wong, L. H., Looi, C. K., Chen, W. Constructivism-informed variation theory lesson designs in enriching and elevating science learning: Case studies of seamless learning design. J Res Sci Teach. 2020,1–23. Wiley Periodicals, Inc. https://doi.org/10.1002/tea.21624

[15] Ting Jing, J., Tarmizi, R. A., Abu Bakar, K., Aralas, D. The Adoption of Variation Theory in the Classroom: Effect on Students' Algebraic Achievement and Motivation to Learn. Electronic Journal of Research in Educational Psychology. 2017, 15(2), 307-325. http://dx.doi.org/10.14204/ejrep.42.16070

[16] World Bank. Ethiopia Education Public Expenditure Review. The World Bank; 2018.

[17] Adamu, A. Y. Challenges of teaching and learning mathematics in secondary schools in Ethiopia. African Journal of Educational Studies in Mathematics and Sciences. 2017, 13(1), 1-12.

[18] Elastika, R. W., Sukono., Dewanto, S. P. Analysis of Factors Affecting Students' Mathematics Learning Difficulties Using SEM as Information for Teaching Improvement. International Journal of Instruction. 2021, 14(4), 281-300. https://doi.org/10.29333/iji.2021.14417a

[19] Alghadari, F., Herman, T., Prabawanto, S. Factors Affecting Senior High School Students to Solve Three-Dimensional Geometry Problems. International electronic journal of mathematics education. 2020, 15(3). https://doi.org/10.29333/iejme/8234

[20] Etang, M. G., Regidor, R. M. Students' mathematical beliefs and attitudes as predictors to students' mathematical ability. International Journal of Education and Social Science Research (IJESSR).2022, 5(3), 23-60. http://dx.doi.org/10.37500/IJESSR.2022.5303

[21] Mohammed, D., Endris, Y. Perceived factors affecting students' mathematics performance in north showa zone secondary schools in Ethiopia. International Journal of Advanced Research in Engineering and Applied Sciences. 2019, 8(5), 21-36. https://www.garph.co.uk

[22] National Educational Assessment and Examinations Agency [NEAEA]. Ethiopian Third National Learning Assessment of grade 10 and 12 students. 2017. Addis Ababa Ethiopia.

[23] Pajares, M. F. Teachers' Beliefs and Educational Research: Cleaning Up a Messy Construct. Review of Educational Research Fall 1992. 1992, 62(3), 307-332. https://doi.org/10.3102/00346543062003307

[24] Pintrich, R. P., Smith, A. F., Garcia, D. T., McKeachie, J. W. (1991). A Manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ). University of Michigan; 1991.

[25] Njoki, P. G.; King-White, D.; Kinai, T., Kigen, E. Assessing the Correlation Between Academic Self-Concept and Mathematics Achievement in Secondary Schools in Nairobi County, Kenya. Journal of Education and Learning. 2019, 8(3), 102-111. https://doi.org/10.5539/jel.v8n3p102

[26] Putwain, D, Symes, W, Nicholson, L., Becker, S. Achievement goals, behavioral engagement, and mathematics achievement: a mediational analysis', Learning and Individual Differences. 2018, 68, 12-19. https://doi.org/10.1016/j.lindif.2018.09.006

[27] Wang, J., Rao, N. Classroom goal structures: Observations from urban and rural high school classes in China. Psychology in the Schools. 2019, 56(8), 1211–1229.

[28] Eccles, J. S., Wigfield, A., Rosenzweig, E. Q. Expectancy-Value Theory and Its Relevance for Student Motivation and Learning. In. The Cambridge Handbook of Motivation and learning, K. A. Renninger, and S. E. Hidi, Eds., Cambridge University Press, 2019, pp. 617-644. https://doi.org/10.1017/9781316823279.025

[29] Ryan, V., Fitzmaurice, O., O'Donoghue, J.Student Interest and Engagement in Mathematics After the First Year of Secondary Education. European Journal of Science and Mathematics Education. 2022, 10(4), 436-454. https://doi.org/10.30935/scimath/12180

[30] Mamiala, D., Mji, A., Simelane-Mnisi, S. Students' Interest in Understanding Geometry in South African High Schools. Universal Journal of Educational Research. 2021, 9(3), 487-496. https://doi.org/10.13189/ujer.2021.090308

[31] Aguilar, J. J. High School Students' Reasons for disliking Mathematics: The Intersection Between Teacher's Role and Student's Emotions, Belief and Self-efficacy. International Electronic Journal of Mathematics Education. 2021, 16(3), em0658. https://doi.org/10.29333/iejme/11294

[32] Detera-Recebido, J. Self-concept and Academic Performance in Mathematics of Senior High School Students. International Journal of Advance Research, Ideas and Innovations in Technology. 2022, 8(3), 385-391. https://www.ijariit.com

[33] Shimelis, A. T., Demeke, W. A. Assessment on students' academic self-efficacy, self-concept, goal orientation and academic achievement: the case of Debre Markos higher education preparatory school, Ethiopia. European Journal of Education Studies. 2017, 3(8), 778-792. https://doi.org/10.5281/zenodo.885443

[34] Wu, H., Guo, Y., Yang, Y., Zhao, L., Guo, C. A Meta-analysis of the Longitudinal Relationship Between Academic Self-Concept and Academic Achievement. Educational Psychology Review. Springer Science and Business Media, LLC; 2021. https://doi.org/10.1007/s10648-021-09600-1

[35] Yunos, N. M., Thangal, T. B. T., Rahmat, N. H., Sharif, N. F. M., Ahmad, S. N., & Latif, N. A. Motivation for Learning Mathematics: A Study Across Disciplines. International Journal of Academic Research in Business and Social Sciences. 2022, 12(9), 1135-1154. https://doi.org/10.6007/IJARBSS/v12-i9/14526

[36] Bandura, A. Self-efficacy: The exercise of control. Freeman. 1997.

[37] Dang, X. C. The Influence of Students' and Teachers' Mathematics-related Beliefs on Students' Mathematics Performance. PhD. Thesis, Flinders University, 2021.

[38] Weißenfels, M., Hofmann, D., Dörrenbächer-Ulrich, L., Perels, F. Linking academic buoyancy and math achievement in secondary school students: Does academic self-efficacy play a role? Current Psychology. 2022. https://doi.org/10.1007/s12144-022-03488-y

[39] Arens, A. K., Frenzel, A., Goetz, T. Self-Concept and Self-Efficacy in Math: Longitudinal Interrelations and Reciprocal Linkages with Achievement, The Journal of Experimental Education. 2020. https://doi.org/10.1080/00220973.2020.1786347

[40] Wang, Q., Xue, M. The implications of expectancy-value theory of motivation in language education. Front. Psychol. 2022, 13: 992372. https://doi.org/10.3389/fpsyg.2022.992372

[41] Herges, R. M., Duffield, S., Martin, W., Wageman, J. Motivation and Achievement of Middle School Mathematics Students. The Mathematics Educator. 2017, 26(1), 83-106.

[42] Pitsia, V., Biggart, A., Karakolidis, A. The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievement: A multilevel analysis of the Programme for International Student Assessment data. Learning and Individual Differences. 2017, 55, 163–173. http://dx.doi.org/10.1016/j.lindif.2017.03.014

[43] Zhang, J., Bohrnstedt, G., Park, B. J., Ikoma, S., Ogut, B., and Broer, M. Mathematics Motivation and the Relationship with Student Performance: Evidence from the HSLS Overlap Sample. Washington, DC: American Institutes for Research; 2021.

[44] Pekrun, R., Schukajlow, S., Rakoczy, K. Emotions and motivation in mathematics education: Theoretical considerations and empirical contributions. ZDM: the international journal on mathematics education. 2017, 49(3), 307-322. https://doi.org/10.25656/01:15859

[45] Seel, N., Lehmann, T., Blumschein, P., Podolskiy, O. Instructional Design for Learning: Theoretical Foundations. Sense Publishers; 2017.

[46] Nisa, C. C., Astriani, D. Application of the guided inquiry learning model to increase student learning motivation. J. PIJAR MIPA. 2022, 17(4), 475-479. https://doi.org/10.29303/jpm.v17i4.3664

[47] Borovay, L. A., Shore, B. M., Caccese, C., Yang, E., Hua, O. Flow, Achievement Level, and Inquiry-Based Learning. Journal of Advanced Academics, 2019, 30(1),74–106. https://doi.org/10.1177/1932202X18809659

[48] Dávila-Acedo, M. A., Sánchez-Martín, J., Airado-Rodríguez, D., Cañada-Cañada, F. Impact of an Active Learning Methodology on Students’ Emotions and Self-Efficacy Beliefs towards the Learning of Chemical Reactions—The Case of Secondary Education Students. Educ. Sci. 2022, 12(347). https://doi.org/10.3390/educsci12050347

[49] Kullberg, A., Ingerman, A., Marton, F. Planning and Analyzing teaching: Using the Variation Theory of Learning. Routledge; 2024. https://doi.org/10.4324/9781003194903-3

[50] Gu, F., Huang, R., Gu, L. Theory and development of teaching through variation in mathematics in China. In Teaching and learning mathematics through variation. R. Huang & Y. Li. Eds. Sense Publishers; 2017, pp. 13–41.

[51] Lomibao, L. S., Ombay S. O. Does Repetition with Variation Improve Students’ Mathematics Conceptual Understanding and Retention? International Journal of Science and Research (IJSR). 2017, 6(6), 2131-2137. https://doi.org/10.21275/ART20174479

[52] Berie, K., Liping Ding. The use of variation theory in a problem-based task design study. Eleventh Congress of the European Society for Research in Mathematics Education, Utrecht University, Utrecht, Netherlands. hal-02423413; 2019.

[53] Handy, J. Theories that Inform the Use of Variation in Mathematics Pedagogy. PhD. Thesis, Alberta University, 2021.

[54] Baskoro, I. Variation theory-based mathematics teaching: The new method in improving higher order thinking skills. Journal of Physics: Conference Series 1957. 2021, 012016. IOP Publishing. https://doi.org/10.1088/1742-6596/1957/1/012016

[55] Lo, M. L. Variation Theory and the Improvement of Teaching and Learning. Acta Universitatis Gothoburgensis; 2012. http://gupea.ub.gu.se/handle/2077/29645

[56] Riegle-Crumb, C., Morton, C., Nguyen, U., Dasgupta, N. Inquiry-Based Instruction in Science and Mathematics in Middle School Classrooms: Examining Its Association with Students’ Attitudes by Gender and Race/Ethnicity. AERA Open July-September. 2019, 5(3), 1–17. https://doi.org/10.1177/2332858419867653

[57] Abza, A., Wodaj, H., Edessa, S. Effects of Guided Inquiry-Based Model on Pre-Service Biology Teachers Attitude Towards Invertebrate Zoology Learning. Aquademia. 2022, 6(2), ep22007. https://doi.org/10.30935/aquademia/12360

[58] Sulistyani, N., Raharjo, E. P. The Effect of The Implementation of Guided Inquiry-Based Worksheet on The Empire Ability and Self-Efficacy of High School Students. PRISMA. 2022, 11(1), 21-31. https://doi.org/10.35194/jp.v11i1.2078

[59] Sabitu, K. A., Lamidi, T. O. Effect of structured and guided investigation techniques on the interest of College students in Mathematics in Nigeria. THE COLLOQUIUM. 2022, 10(1), 83-92. www.ccsonlinejournals.com

[60] Pillay, V., Adler, J., Runesson Kempe, U. The sequencing and pairing of examples in the midst of sameness and difference: Opening opportunities to learn. Pythagoras. 2022, 43(1), a667. https://doi.org/10.4102/pythagoras.v43i1.667

[61] Dorier, J., Maass, K. Inquiry-Based Mathematics Education. In Encyclopedia of Mathematics Education. S. Lerman, Ed. Springer Nature Switzerland AG.; 2020, pp. 384-389. https://doi.org/10.1007/978-3-030-15789-0