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Instructional use of Geometer's Sketchpad and students geometry learning motivation and problem-solving ability

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Abstract
This study investigated Geometer's Sketchpad (GSP) supported instruction and students' geometry learning motivation and problem-solving ability (PSA). A pre-/post-test quasi-experimental design with non-equivalent comparison groups was used on two intact groups of grade 9. An instruction of four weeks' duration was given to the intervention group. The motivation measuring questionnaire, self-efficacy measuring questionnaire, effort measuring questionnaire, and PSA measuring questions were used to collect data. The internal consistency reliability was above 0.8 for each questionnaire. Paired and independent sample t-tests, ANOVA, and regression analysis were used. Findings indicated a statistically significant difference between the intervention and comparison groups and achiever levels after the treatment in both motivation and PSA, and a high correlation was observed between motivation and problem-solving. Components of motivation significantly accounted for both motivation and PSA. The use of GSP-supported instruction is recommended to improve students' motivation and problem-solving abilities.

Keywords: Geometer's Sketchpad, self-efficacy, effort, motivation, problem-solving ability

INTRODUCTION

Science and technology are advancing these days, and teaching supported by a number of software programs is becoming evident. For the advancements hitherto, the role of mathematics is high, and geometry as a branch of mathematics, also plays a great role in science and technology. As mathematics contributes to the development of science and technology, technology also contributes to the development of mathematics. Other countries' research findings show that computers play an important role in educational contexts, so they are encouraged in mathematics classrooms (Phonguttha et al., 2009). Goldenberg (2000) also suggests that the power of new technologies is one of the strongest forces in the contemporary growth and evolution of mathematics and mathematics teaching. It is so because it helps in presenting and connecting multiple representations and serving as a tutee (Cullen et al., 2020). Among the various technologies, computer programs are used to increase the importance of certain ideas, solve problems, make topics more accessible, and also provide new ways to represent ideas, choose content, and determine the type of pedagogy used. There are various types of technology used in mathematics. One of these technologies is Geometer's Sketchpad (GSP). Due to the significant role that GSP plays, mathematics educators are encouraged to put it as an appropriate technology into effect at all grade levels, ability levels, and in different areas of content (Phonguttha et al., 2009). There is a sufficient supply of various types of dynamic geometry software, but GSP is one of those that can be used by students and teachers as an instrument to help them learn geometry (Hartono, 2020). Despite this, there are varying study reports in relation to the use of GSP and its effect on various variables such as achievement, attitude, and problem-

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Contribution to the literature

- This study contributes to the ongoing debate about using technology and its impact on motivation and problem-solving. It further informs pedagogical approaches for improved motivation and problem-solving in low-income nations that have limited access to technology and connectivity.
- It contributes to the research needs to understand the relationship between PSA and the two components of motivation in students at different achievement levels.
- It also provides information on how much integrating technology with the geometry curriculum is important for low-income nations.

solving. The study of Idris (2007) indicated the significant differences in geometry achievement of the experimental groups as compared to the control groups indicate that GSP shows promising implications for the potential of using GSP in teaching geometry at the secondary school level. Ames (2011), in his turn, indicated that students who used GSP demonstrated increased inductive reasoning when learning geometry and the properties of quadrilaterals. Even though an increase in motivation or conceptual knowledge was not found to be significant, informal observations showed that higher-achieving students tended to display greater motivation and on-task time when using GSP. Eu (2013) also indicated the use of GSP in the mathematics classroom has a positive effect on the students' mathematics achievement and their attitude towards the learning of graphs of functions also improved. Students' achievement in GSP showed a positive impact on students' achievement in geometry, as indicated by the increase in their post-test scores (Roble, 2016). Hartono (2020) also concluded that GSP learning was effective in two-dimensional shape learning. The circle properties had improved students' understanding, and the analysis of the questionnaire showed positive feedback on the use of GSP in the learning of circles (Ganesan & Eu, 2020). The use of GSP as a teaching tool improved students' perception and their achievement in mathematics (Latha, 2020).

In spite of the above notes, there was a negative impact on the use of technology (Bakar et al., 2009), though time constraint might be one of the reasons why this study came up with this result. Students have both positive and negative thoughts towards instructional software and GSP as a virtual manipulative (Gecu & Satici, 2012). The difference in van Hiele's level of geometric thinking between students in the experimental group and in the control group was not significant for the post-tests (Tieng & Eu, 2014). There were significant differences between different students in terms of school performance levels, grade levels, and genders in their use of ICTs (one of which was GSP) in learning mathematics (Fan et al., 2022).

The literature indicates that the use of GSP is still a research area and can also be seen in terms of context. GSP program and its association with students' geometry learning motivation and students' problem-solving ability (PSA) are among the areas of investigation that are not well studied, especially in low-income countries where there is limited access and exposure to technology use for education.

Motivation is another important construct for mathematics learning since it is suggested that motivation plays an important role in enhancing student learning and performance. When learning with the help of technology, students are expected to learn concepts on their own and with amicable demonstrations and help tools. In technology mediated environments, where students must take an active role in their learning by self-directing, motivation is essential to learning and performance (Lee, 2000, as cited in Gabriel, 2008). In contrast, Wong and Wong (2021) argue that in a technology-enhanced learning context, despite the improved motivation mean scores for the experimental group after an intervention, the improvement was not significant. Hull et al. (1999) in their turn concluded that the use of GSP software improves student interest, enjoyment, and participation in learning geometry. These indicate varying positions. While some note that classroom instructions should be supported with appropriate technology (Peterson et al., 2007), studies like that of Wong and Wong (2021) did not show a significant contribution, specifically to motivation. Projectors, for example, can increase interaction and interest while also improving motivation in schools and colleges (Raja & Nagasubramani, 2018). Beyond motivation, it is also underscored that computer technology and mathematical problem-solving have a strong relationship. In addition to this, technology is reported to give a chance for students to solve mathematical problems. Technologies are also reported to help students become mathematical problem solvers and give them a chance to solve problems in real-life situations rather than just doing routine problems (DimaKos & Zaranis, 2010). Nonetheless, according to Carstens et al. (2021), there are many positive and negative aspects to technology use in the classroom. Computer technology is greatly influencing the way we solve mathematical problems (Li et al., 1997). Mathematical problem-solving considers phases students need to consider, and these phases can be managed well when solving mathematical problems in technology-mediated environments. Raja and Nagasubramani (2018) indicated that

> Education is essential in corporate and academic settings. In the former, education or training is used to help workers do things differently than they did before. In the latter, education is geared towards creating curiosity in the minds of students. In either case, the use of technology can help students understand and retain concepts better.

Though the role and use of technology for learning is argued, the time is demanding to interface education with technology and explore ways technology can contribute to better learning through mitigation of its limitations. It is thus essential to look into the relationship between GSP-mediated learning and students' motivation and PSA, but in the context of a low-income nation.

Statement of the Problem

It is well known that mathematics is a crucial subject for the development of science and technology, and it is known to help students develop their motivation and math problem-solving abilities. The better problem-solving skills students possess, the more likely they are likely to be motivated to learn mathematics. As stated in the education and training policy of Ethiopia (TGE, 1994), one of the general objectives is to develop the physical and mental potential and problem-solving capacity of individuals. Moreover, raising students' creativity and interest and making education a supportive tool for developing traditional technology and utilizing modern technology are among the specific objectives. In order to prepare a generation that is competent and skillful and to develop their ability, positive attitude, and ability to solve problems, and to promote their motivation to learn in the 21st century, the use of technology is paramount. Despite these, the motivation of students in secondary and preparatory schools to learn mathematics in general and geometry in particular seeks use of technology. In Ethiopia, a significant number of students fail to develop adequate understanding of geometry concepts, problem-solving skills, and their overall achievement (NEAEA, 2020). In the region in which the study site was located, it is shown that students' academic achievements are decreasing with a fluctuating pattern within the last three years (Kene et al., 2021). Several factors can be mentioned for this problem, but teaching methods, absence or inappropriate use of technology, problems related to curriculum design, and preparation of textbooks can be a few. Among these, instruction should be given priority as it has a direct and significant impact on students' motivation and PSA. As a district located around 60 km from the capital city of Ethiopia, access to computer-based instruction was not simple, despite the expansion that has been undertaken in the last few years. So, technology use for instructional purposes was limited previously, but students have access to computers these days. Given the provision of access to computers, it is worth investigating how these can be used to help students learn better. It is also well documented that technology-mediated instruction is emancipatory. Dekker (2011), after his study on the effect of GSP on student knowledge and attitude, indicated that mathematics educators are encouraged to carry out similar studies once this technology is more familiar to students. Thus, this study was conducted since there was no study in relation to technology use in the area in general and GSP in particular, and it tried to explore the implementation of technology mediated instruction–specifically the use of GSP mediated instruction–and its impact on student motivation and PSA. This was attempted to explore if the use of technology could show some learning for action towards improving the motivation and problem-solving capability of students, which is a recurring problem in the area. The study also considered achiever levels and classified students into three achiever level groups: low, medium, and higher achievers. This grouping was used to see student capability differences with the use of GSP for the motivation and problem-solving abilities in learning geometry.

Research Questions

The study answered the following questions:

1. What is the effect of using GSP in geometry instruction on students' geometry learning motivation and with respect to achiever levels?
2. What is the effect of using GSP in geometry instruction on students' PSA and with respect to achiever levels?
3. Is there a significant difference in motivation and PSA between the achiever levels as a consequence of learning with a GSP?
4. What association is there between student motivation and their PSA when they learn supported by GSP?

Theoretical Framework

Learning can be conceptualized from a variety of perspectives, including styles, instruction, material use, and philosophical and epistemological foundations. These days, technological advancement has brought a number of values, challenges, and opportunities for learning. The proposal to use technological pedagogical content knowledge raised the issue of integrating technology into the learning process. Geometry as a spatial or axiomatic subject requires visualization that could be better handled with the use of technology suitable for the purpose.

According to Keengwe et al. (2008), learning ensures productive, interesting, motivating, interactive, and quality delivery of classroom instruction through the application of multi-media technologies, and these are useful to address diverse learners' needs. Davis (1989), a proponent of the technology acceptance model, posited that perceived usefulness and perceived ease of use are the two fundamental determinants of actual system use in learning. The proponents of the technology acceptance model argue that if learners find a technology useful and easy to use, then they will develop a positive attitude toward using the technology. Nonetheless, the actual use of a technology is an important factor. Thus, the theory of acceptance and use of technology is viewed as important to guide this study.

There are a number of tools that can be used to learn geometry, such as GSP. GSP was designed to assist the user in learning geometry through observation and the creation of "dynamic" changes to geometric objects (Lester, 1996). The ease of use of technology and the development of conceptual understanding through the use of visible supports with software such as GSP are believed to support the development of problem-solving skills and can boost motivation to learn. This study, therefore, applies the theory of acceptance and use of GSP to see the effect on students' geometry learning motivation and PSA.

MATERIALS AND METHODS

This study employed quantitative methods since it was trying to explore motivation and PSA at the same time through cross-sectional data of a quasi-experimental type. The study used quasi-experimental research to establish an effect of the instructional approach and a systematic and logical association between manipulated factors and observed factors.

Design of the Study

The design for the study was a non-equivalent group pre-test post-test quasi-experimental design. This was useful to know the effect of the treatment applied to the intervention group (IG) and the comparison group (CG), and to devise ways to uncover condition effects. This was chosen since it was not possible to randomly assign the groups, but rather to consider intact groups in schools.

The pre-test was required for both groups before the intervention in order to have some idea of how similar or different the two groups were. Similarly, the post-test was required to know the effect of the intervention. One intervention and one CG were considered for this study. IG received the instruction with GSP, and CG received only the traditional paper-pencil instruction. The intervention was implemented for four weeks on the concept areas of triangles and parallelograms.

Population and Participants of the Study

This study was conducted at Chancho Abageda Secondary and Preparatory School, a governmental school located in the Oromia Special Zone surrounding Finfinne, located at Sululta Woreda. The researchers chose the school because one of the researchers works there indicating that convenient sampling was used. Grade 9 students were the target of the study. There were 769 grade 9 students, with 422 male and 347 female students. There were 10 sections of grade 9 students at the school. Hence, the population of the study encompasses all the sections of grade 9 students in the school. From among the available sections, two naturally assembled groups were considered intact classes. For selecting two equivalent sections (groups), the mean scores and standard deviations based on their academic records from the prior semester were used. This was used as the criteria for sampling. Accordingly, two sections that were at equivalent levels based on the mean score and standard deviation were selected for the study. After selecting the two sections, one of them was randomly assigned as a treatment group and the other as a CG. All students in these two sections were participants in the study. IG consisted of 68 students, and CG had 65 students. Students in both groups were also classified into three as lower, medium, and higher achievers based on their first semester mathematics results of the same academic year by using the ministry of education standards for achiever levels. Students who scored less than 50, between 50 and 74 (inclusive), and more than 74 were considered as low, medium, and high achievers, respectively.

Data Collection Instruments

Motivation measuring questionnaire

For this particular study, a motivation measuring questionnaire (MMQ) was used, which had two parts: self-efficacy measuring questionnaire (SEMQ) and effort measuring questionnaire (EMQ). The self-efficacy related items were adapted from Betz and Hacke's (1981) questionnaire with slight modification by the researchers.

Items were rated on a five-point Likert-scale type, 1=strongly disagree to 5=strongly agree, and consisted of 14 items, half of which were positively worded and half negatively worded, so that students could evaluate each item on its own right and to protect students from evaluating the items equally. Similarly, the effort-related items were adapted from Agbuga (2010) with slight modification by the researcher. These were a seven-point Likert scale type that consisted of eight items in which the level of agreement ranged from 1=not at all true to 7=very true.

Problem-solving ability measuring questionnaire

In order to measure students' PSA, open-ended questions involving multi-step solutions were developed by the researchers. These questions were taken from the textbooks and references, and they were pilot tested. Students' PSA was measured at each Polya stage (understanding the problem, devising a plan, carrying out a plan, and looking back). Each Polya stage was accompanied by four scale lengths of rubrics measured (0, 1, 2, & 3). By using this, students' PSA was measured at each Polya stage using a performance assessment rubric. The point zero was given if a student gave no response at all, one was given if a student responded somehow but not all of it was appropriate, two was given if a student responded but missed a significant part, and three was given if a student responded completely and appropriately.

Reliability and Validity of the Instruments

MMQ has two parts: SEMQ and EMQ; and PSA measuring questionnaire are adapted from validated tools in other contexts. Since the instruments were previously validated, the use of these supports the construct validity, but, in the context of this study, they were somehow modified and had to go through the reliability and validation process. For face and content validity, the tools were reviewed by experts at the Department of Science and Mathematics Education at Addis Ababa University, and all the tools went through pilot testing at Meskerem Secondary School, which was not included in the study. The reliability coefficients for each were more than 0.7 (in an acceptable range to accept their internal consistency reliability). The alpha coefficients of the final data gathered for the study are also given below. Given the limitation on the sample size and absence of replications, the external validity might be challenged, and hence the conclusion to be drawn from this study has to be done cautiously.

Data Collection Procedure

Once the SEMQ, EMQ, and PSAMQ instruments were developed and pilot tested, the next step was to collect data to undertake the study. For internal consistency, the reliability alpha values were 0.87 for SEQM, 0.90 for EMQ, and 0.84 for PSAMQ, respectively. To this end, the SEMQ, EMQ, and PSAMQ were administered as pre-tests to both groups to get information on student self-efficacy, effort, and PSA a week prior to the intervention. The same instruments were administered to both groups a week after the treatment was completed to see whether there was a difference between the groups as a result of the different teaching methods. Moreover, PSAMQ was given first and followed by EMQ both during pre-tests and post-tests.

Methods of Data Analysis

Owing to the purpose of the study, both descriptive and inferential analyses such as comparisons and regression were conducted. The pre-test-post-test mean scores and standard deviations of both the experimental and comparison groups were determined, and to compare differences between the groups, an independent sample t-test was used. To look into the improvement in motivation and PSA from the pre-test to the post-test within the same group, a paired sample t-test was used. Analysis of variance was also used to measure self-efficacy, effort, and PSA with respect to the three achiever levels. Moreover, regression analysis was also used to know the effect of self-efficacy and effort on students' PSA. Furthermore, to know the effect of the treatment, Cohen's (1988) effect size (ES) formula was used. According to Cohen (1988), ES of .2 and less is a small effect; greater than .2 and less or equal to .5 is a modest effect, greater than .5 and less or equal to .8 is a moderate effect; greater than .8 and less or equal to one is a large effect; and greater than one is a strong effect.

RESULTS AND DISCUSSION

The results for each of the analyses guided by the objectives and research questions of the study are described below. In order to figure out if there were differences between the two groups before the intervention began, an independent samples t-test was conducted to examine their achievement levels in both motivation and problem-solving. There was no statistically significant difference between the two groups, $t(131)=0.008$; $p=.994$, and no significant difference was observed between each group of achiever levels: low achievers (LAs) $t(16)=0.031$; $p=.976$; medium achievers (MAs) $t(97)=-.157$; $p=.876$, and high achievers (HAs) $t(14) = 0.118$; $p = .908$. The self-efficacy, effort, and problem-solving abilities of the groups with respect to achiever level sub-groups were compared, likewise. No differences were observed. These all show that the groups were equivalent in the initial phase of the intervention.

Motivation

Motivation as a psychological tool, whether intrinsic or extrinsic, is approached differently by different scholars. An important aspect of determining how to measure motivation is an understanding of what type of motivation one is attempting to capture (Touré-Tillery & Fishbach, 2014), whether process-oriented or outcome-oriented. In this study, self-efficacy and effort are considered to measure motivation. There is also the possibility of measuring motivation using self-reports (Touré-Tillery & Fishbach, 2014). Thus, the self-reported SEMQ and EMQ were used.

After conducting the intervention-teaching by using GSP, pre-post comparisons were conducted to see if

Table 1. Self-efficacy & effort pre-/post-test comparison for experimental & comparison groups with respect to achiever level

Variables		Groups	n	Pre-test		Post-test		t	p	ES
				M	SD	M	SD			
Self-efficacy	LA	IG	10	2.01	.14	2.77	.66	-3.600	.00	1.50
		CG	8	2.07	.09	2.12	.10	-1.600	.14	
	MA	IG	50	2.75	.32	2.90	.38	-4.062	.00	.39
		CG	49	2.70	.35	2.72	.37	-.274	.808	
	HA	IG	8	4.24	.18	4.27	.20	-.600	.567	.10
		CG	8	4.17	.31	4.22	.29	-.691	.512	
Effort	LA	IG	10	3.06	.50	3.63	.60	-3.700	.00	1.00
		CG	8	3.09	.26	3.08	.25	.552	.59	
	MA	IG	50	3.06	.71	3.96	1.04	-9.852	.00	1.01
		CG	49	3.18	.72	3.19	.69	-.299	.766	
	HA	IG	8	4.98	.94	5.28	.64	-4.596	.345	.38
		CG	8	4.28	.64	5.36	.66	-.919	.388	

Table 2. t-test for independent samples comparison of post-test self-efficacy & effort between intervention & comparison groups with respect to achiever levels

Variables		Groups	n	M	SD	df	t	p	ES
Self-efficacy	LA	IG	10	2.77	.66	16	2.778	.013	2.35
		CG	8	2.12	.11				
	MA	IG	50	2.90	.38	97	2.425	.017	.51
		CG	49	2.71	.37				
	HA	IG	8	4.27	.20	14	.386	.705	.20
		CG	8	4.22	.29				
Effort	LA	IG	10	3.63	.63	16	2.297	.035	1.10
		CG	8	3.08	.26				
	MA	IG	50	3.96	1.04	97	4.188	.000	.84
		CG	49	3.21	.707				
	HA	IG	8	5.69	.64	14	1.00	.332	.37
		CG	8	5.36	.66				

differences were observed as an effect of the intervention for self-efficacy and effort with respect to achiever levels. Motivation was also considered as a sum of the two. To this end, the paired sample t-test was used to evaluate the improvement within the same group from pre-test to post-test. Moreover, in order to know the magnitude of the effect of the treatment, Cohen's (1988) ES was used, and the results are presented in **Table 1**.

The results of the paired sample t-test presented in **Table 1** showed that both IG and CG demonstrated improvement in the mean scores for both self-efficacy and effort. This is expected since learning took place irrespective of the approach. But only the low and MAs of IG demonstrated statistically significant improvement in their self-efficacy $t(10)=-3.6$, $p=.00$, ES=.15 for the LAs and $t(10)=-4.062$, $p=.00$; ES=.39 for the MAs, and effort $t(10)=-3.7$, $p=.00$, with an ES of 1.0 for LAs and $t(50)=-9.852$, $p=.00$ for MAs with an ES of 1.01. These show the impact of using GSP to influence the development of self-efficacy and effort and that it impacts better on low and medium-achieving students as compared to high-achieving students, for whom there was no significant difference in effect. A similar study on the effectiveness of GSP learning in two-dimensional shapes indicated that students in the experimental group performed better using GSP than the control group, and the students in the experimental group performed better in the post-test compared to the control group (Hartono, 2020), which stands to be the same as the result of this study, but for the HA students. The study by Eu (2013) also indicated that the use of GSP in the mathematics classroom is useful in helping students perform better in graphing functions and have a positive attitude towards learning the graphing of functions and mathematics with the usage of GSP. These indicate the usefulness of using GSP for the overall success in learning mathematics and attitude-related constructs that include motivation. In addition to the pairwise comparisons with respect to the achiever levels, an attempt was made to compare the mean differences between IG and CG attributed to the different methods of teaching, and an independent samples t-test was used. The self-efficacy as well as effort of IG and CG were compared and the magnitude of ESs calculated. The results are presented in **Table 2**.

The post-test results showed that mean (M)=2.77, standard deviation (SD)=.66 for IG and M=2.12, SD=.11 for CG. Moreover, $t(16)=2.778$, $p<.05$, indicating that

Table 3. Pre-/post-test problem-solving ability comparisons between intervention & comparison groups for low achiever groups

Subscales	Groups	n	Pre-test		Post-test		t	p	ES
			M	SD	M	SD			
Understanding	IG	10	.79	.22	1.22	.398	-3.254	.010	.56
	CG	8	.77	.21	.81	.250	-1.423	.136	
Devising a plan	IG	10	.85	.077	1.22	.266	-4.145	.003	.71
	CG	8	.82	.57	.78	.100	1.426	.205	
Carrying out plan	IG	5	.71	.22	1.04	.150	-5.412	.006	1.70
	CG	4	.61	.14	.69	.170	-3.000	.058	
Looking back	IG	4	.25	.32	.89	.160	-5.569	.011	1.80
	CG	4	.33	.24	.50	.060	-1.441	.245	

there was a statistically significant difference between the intervention and comparison groups in students' self-efficacy after the intervention of the lower achiever groups. The magnitude of the effect was 2.35, showing that the instruction supported with GSP increased the mean scores of self-efficacy of students in the lower achiever category. The post-test results for effort were M=3.63, SD=.63 for IG, and M=3.08, SD=.26 for CG. Furthermore, t(16)=2.297, p<.05 indicates that there was a statistically significant difference in effort between the intervention and comparison groups as a result of the intervention of GSP mediated instruction. ES d=1.1 shows a strong effect of the treatment/intervention.

The result was the same for the medium-achievement student group, where M=2.90, SD=.38 for IG and M=2.71, SD=.37 for CG. Moreover, t(97)=2.425, p<.05 indicates that there was a statistically significant difference between the intervention and comparison groups in students' self-efficacy after the intervention of the medium-achievers groups. The magnitude of the effect was d=.51, which is larger than typical, showing that the instruction supported with GSP increased the mean scores of self-efficacy of students in the MA group. The post-test results for effort were M=3.96, SD=1.04 for IG, and M=3.21, SD=.71 for CG. Furthermore, t(97)=4.188, p<.05 indicates that there was a statistically significant difference in effort between the MA group students as a result of the intervention of GSP mediated instruction between the intervention and comparison groups. ES, d=.84 shows a strong effect of the treatment/intervention. The higher-achieving student group did not manifest any differences. This seems to be reasonable since HAs been likely to be highly motivated irrespective of the instructional approach, and those could be the ones who exert maximum effort to fulfil their motivation. From the overall motivation measures of self-efficacy and effort, the conclusion was made that there was a statistically significant difference between IGs and CGs during the post-test, showing the effect of the intervention in enhancing motivation of the lower and medium-achieving students, but not for higher achievers. The findings of Eu (2013) and Hartono (2020) are some results that support the findings of this study. However, Ames (2011) in his study on the effect of incorporating GSP into a high school geometry course to improve conceptual understanding, inductive reasoning, and motivation, indicated that students who used GSP demonstrated increased inductive reasoning when learning geometry and the properties of quadrilaterals. The author further indicated that even though an increase in motivation or conceptual knowledge was not found to be significant, informal observations showed that higher-achieving students tended to display greater motivation and on-task time when using GSP. This study, however, showed a contrary result, where HAs did not show any significant difference. The contending results are indicative of the need to conduct further study to better learn the effect of GSP on HAs.

Problem-Solving

Improvement of PSA is a fundamental outcome of education. The intervention of instruction with the support of GSP was attempted to see if it significantly contributes to developing PSA. PSA also differs among students of different achievement levels. High-achieving students are expected to have better problem-solving abilities than the lower-achieving group of students. Thus, it is essential to make this comparison across the different achiever groups. In this regard, the improvement in PSA of students from each of the achiever levels from pre-test to post-test was compared using the paired sample t-test.

Table 3 presents the result of the paired sample t-test of each group of achiever levels with respect to Polya's levels of problem-solving.

The paired sample t-test results in **Table 3** show that M=.79, SD=.22 in the pre-test and M=.22, SD=.40 in the post-test for IGs. Furthermore, t(9)=-3.254; p<.05 indicates that IG, but not CG, has a statistically significant difference between the pre- and post-test. This means instruction supported with GSP enhances students' problem understanding for problem-solving as compared to the traditional method. ES d=.56 shows a moderate effect.

In a similar way, the intervention brought a statistically significant difference in each level of problem-solving: t(9)=-4.145, p<.05 for devising a plan;

Table 4. Paired samples t-test for PSA pre-/post-test comparison for intervention & comparison groups for medium achievers

Subscales	Groups	n	Pre-test		Post-test		t	p	ES
			M	SD	M	SD			
Understanding	IG	50	1.32	.49	1.68	.46	-6.491	.00	.75
	CG	49	1.42	.45	1.36	.46	1.071	.289	
Devising a plan	IG	50	1.55	.66	1.86	.43	-5.726	.00	.56
	CG	49	1.5	.61	1.58	.55	-1.639	.108	
Carrying out plan	IG	24	1.26	.57	1.67	.51	-4.068	.000	.76
	CG	30	1.13	.40	1.2	.41	1.512	.141	
Looking back	IG	23	.92	.75	1.29	.64	-2.371	.027	.53
	CG	24	1.06	.53	.898	.66	.991	.332	

Table 5. Paired samples t-test for PSA pre-/post-test comparison for intervention & comparison groups for high achievers

Subscales	Groups	n	Pre-test		Post-test		t	p	ES
			M	SD	M	SD			
Understanding	IG	8	2.19	.32	2.15	.34	.570	.587	.12
	CG	8	2.03	.29	1.99	.42	.580	.580	
Devising a plan	IG	8	2.19	.36	2.27	.26	-1.126	.297	.26
	CG	8	2.06	.33	2.11	.37	-1.528	.170	
Carrying out plan	IG	7	1.84	.83	1.92	.79	-1.355	.224	.10
	CG	7	1.89	.33	1.98	.42	-1.870	.111	
Looking back	IG	7	1.68	.75	1.73	.74	-.884	.411	.07
	CG	7	1.73	.29	1.76	.32	-.795	.457	

Table 6. PSA post-test comparison between intervention & comparison groups for lower achiever groups

Subscales	Groups	n	M	SD	df	t	p	ES
Understanding	IG	10	1.22	.39	16	2.549	.021	1.20
	CG	8	.807	.25				
Devising a plan	IG	10	1.22	.27	16	4.420	.000	2.10
	CG	8	.78	.101				
Carrying out plan	IG	6	1.07	.15	8	3.736	.006	2.40
	CG	4	.69	.17				
Looking back	IG	5	.93	.17	7	4.827	.002	3.20
	CG	4	.50	.06				

$t(4)=-5.412$, $p<.05$ for carrying out a plan; and $t(3)=-5.569$, $p<.05$ for looking back. But no difference was observed in any one of the achiever levels in CG.

The comparison in PSA of the MAs was also computed using the paired samples t-test to see their improvement from pre-test to post-test and the results are presented in **Table 4**.

The results in **Table 4** indicate the same findings for the MAs similar to the lower achievers with M=1.32, SD=.49 in the pre-test and M=1.68, SD=.46 in the post-test for understanding with $t(49)=-6.491$; $p<.05$; M=1.55, SD=.66 in the pre-test and M=1.86, SD=.43 in the post-test for planning with $t(49)=-5.726$; $p<.05$; M=1.26, SD=.57 in the pre-test and M=1.67, SD=.51 in the post-test for carrying out plan phase with $t(23)=-4.068$; $p<.05$, and M=.92, SD=.75 in the pre-test and M=1.29, SD=.64 in the post-test for looking back with $t(22)=-2.371$; $p<.05$. No significant difference was observed for CG.

The results were also vital to make a comparison of PSA for the upper groups between pre- and post-test in order to see whether there was a significant improvement, and the results did not show any statistically significant difference ($p>.05$) the result of which is presented in **Table 5**.

An independent samples t-test was also conducted for the comparison of the mean scores of PSA for each level of problem-solving between the post-test for the IG and CG of each achiever level. The independent samples t-test results for lower groups are presented in **Table 6**.

The post-test results for the lower achiever groups revealed that IG significantly improved in their PSA for each level of problem-solving ($p<.05$) with a very large ES ($d>1.0$).

A similar comparison was conducted for the MAs of both the intervention and comparison groups. The result is given in **Table 7**.

The post-test results for the MA groups revealed similar findings: IG significantly improved in their PSA for each level of problem-solving ($p<.05$) with a high ES of between 0.46 and 0.66.

From the results above, the effect of GSP on motivation and PSA was discussed for particular

Table 7. PSA post-test comparison between intervention & comparison groups for medium achiever groups

Subscales	Groups	n	M	SD	df	t	p	ES
Understanding	IG	50	1.59	.50	97	2.631	.010	.53
	CG	49	1.335	.45				
Devising a plan	IG	50	1.81	.52	97	2.188	.031	.66
	CG	49	1.56	.59				
Carrying out plan	IG	33	1.6	.42	61	3.888	.000	.46
	CG	30	1.2	.41				
Looking back	IG	20	1.56	.46	39	3.543	.001	.51
	CG	21	1.03	.48				

Table 8. An ANOVA test of mean difference in self-efficacy between different achiever levels of intervention group (n=68)

Variables	df	SS	MS	F	p
Between groups	2	13.830	6.915	40.130	.000
Within groups	65	11.200	.172		
Total	67	25.030			

Table 9. Tukey HSD test of mean difference in self-efficacy between different achiever levels of intervention group

I	J	MD (I-J)	SE	p	95% CI	
					LB	UB
LA	MA	-.1257	.1438	.658	-.4706	.2192
	HA	-1.4978*	.1969	.000	-1.9701	-1.026
MA	HA	-1.3721*	.1581	.000	-1.7512	-.9930

Note. CI: Confidence interval; MD: Mean difference; LB: Lower bound; & UB: Upper bound

Table 10. An ANOVA test of mean difference in effort between different achiever levels of intervention group (n=68)

Variables	df	SS	MS	F	p
Between groups	2	23.384	11.692	12.750	.000
Within groups	65	59.608	.917		
Total	67	82.992			

Table 11. Tukey HSD test of mean difference in PSA between different achiever levels of intervention group

I	J	MD (I-J)	SE	p	95% CI	
					LB	UB
LA	MA	-.3350	.3317	.573	-1.1307	.4607
	HA	-2.0625*	.4542	.000	-3.1520	-.9730
MA	HA	-1.7275*	.3647	.000	-2.6021	-.8529

Note. CI: Confidence interval; MD: Mean difference; LB: Lower bound; & UB: Upper bound

achiever groups: lower, medium, and higher, and between pre- and post-test. A comparison of the achiever levels on the post-test was also performed. These were conducted to check if the achiever levels changed in their characteristics as a consequence of the use of GSP. To that end, the effect of the intervention on the three variables: self-efficacy, effort, and PSA was further analyzed to see the magnitude of the effect on each group of achiever levels within IG that included ANOVA and multiple regressions.

As shown in **Table 8**, $F(2, 67)=40.130$ $p<.05$. From this, it can be concluded that there are statistically significant differences in students' self-efficacy between the achiever level groups of low, medium, and high. From the previous discussions and the results depicted in **Table 8**, it is evident that instruction supported with GSP helped the IG to enhance students' self-efficacy within and between the achiever level groups.

In order to investigate between which achiever level groups, the difference was statistically significant, a post-hoc Tukey HSD was conducted, and the results are presented in **Table 9**.

According to the Tukey HSD results in **Table 9**, the pairwise comparison of self-efficacy was statistically significant for lower achievers versus HAs and MAs versus HAs ($p<.05$). But no significant difference was observed between low and MAs.

Similarly, the mean difference across the achiever levels was compared for effort using ANOVA to see whether instruction supported with GSP had a significant impact in improving students' effort. The result of the ANOVA is presented in **Table 10**.

According to the ANOVA test, there is a statistically significant difference in effort between the three achiever level groups ($F[2, 65]=12.75$, $p<.001$). To know between which groups the significant difference occurred, the Tukey HSD test was performed.

According to the Tukey HSD analysis (**Table 11**), the mean score of effort of the lower achievers differed significantly from the mean score of the HAs ($p<.05$), and the MAs differed significantly from the HAs in their effort. But no significant difference was observed between low and MAs. This leads to the conclusion that GSP-supported instruction increased student effort to learn geometry concepts.

A similar analysis was conducted for PSA, and the result is presented in **Table 12**.

From **Table 12**, the result $F(2,65)=15.52$, $p<.05$ indicates differences in students' PSA were significantly significant between the three achiever level groups of low, medium, and high.

A post-hoc analysis was conducted to learn more about which groups differ significantly, and the result is presented in **Table 13**.

Table 12. An ANOVA test of mean difference in PSA between different achiever levels of intervention group (n=68)

Variables	df	SS	MS	F	p
Between groups	2	3.998	1.999	15.515	.000
Within groups	65	8.374	.129		
Total	67	12.371			

Table 13. Tukey HSD test of mean difference of PSA between different achiever levels of intervention group

I	J	MD (I-J)	SE	p	95% CI	
					LB	UB
LA	MA	-.4851(*)	.12433	.001	-.7833	-.1868
	HA	-.9414(*)	.17025	.000	-1.3498	-.5330
MA	HA	-.4564(*)	.13667	.004	-.7842	-.1285

Note. *The mean difference is significant at the .05 level; CI: Confidence interval; MD: Mean difference; LB: Lower bound; & UB: Upper bound

From the Tukey HSD, we can see that the PSA of the lower achiever group was significantly lower than both the medium and HA groups. Likewise, the MA group was different from the HA group, unlike the motivation for which the lower achiever and MA groups failed to demonstrate significant differences. Since the improvement was positive from the pairwise comparison between the pre- and post-test of IG, the observed significant difference between achiever level groups shows that the teaching with GSP helped the students in IG to create opportunities to solve geometrical problems and enhance their PSA across the achiever levels.

Having identified the effect of GSP-supported instruction on the motivation and PSA of students, it was useful to look at how these two variables relate to each other. To this end, correlation analysis was conducted to see the relationship between motivation and PSA. It was found that there was a positive correlation showing a positive contribution of PSA to motivation and vice versa. This idea is in alignment with some research reports. In this regard, Weith and Burns (2005) stated that, under appropriate conditions, motivation may help develop an insight into problem-solving and contribute to the ability to solve problems. The motivation to deal with problem-solving tasks can come from the learners themselves or be triggered by task design (Urhahne, 2021). Based on several problem-solving models, O'Neil and Schacter (1997) developed the CRESST model of problem-solving that incorporates four elements: content understanding, problem-solving strategies, metacognition, and motivation, in which motivation is a considered factor for problem-solving.

In addition to the aforementioned results, regression analysis was performed to see the effect of components of motivation, in this case self-efficacy and effort, on PSA. The analysis was conducted on lower, and MAs as higher achievers had higher levels of motivation and problem-solving for which no significant difference was observed. The results of the regression analysis are given in **Table 14** and **Table 15**.

Table 14. Regression analysis of variables of motivation (self-efficacy & effort) & problem-solving ability of lower achievers of intervention group

ANOVA					
	SS	df	MS	F	p
Regression	.682	2	.341	153.143	.000
Residual	.016	7	.002		
Total	.698	9			

Variables in regression equation						
Model	R	B	SE	Beta	t	P
Constant	-	-.100	.112		-.894	.401
Self-efficacy	.978	.224	.078	.527	2.868	.024
Effort	.975	.210	.081	.474	2.579	.037

Note. Multiple R=.989 & R^2=.978

Table 15. Regression analysis of variables of motivation (self-efficacy & effort) & problem-solving ability of medium achievers of intervention group

ANOVA					
	SS	df	MS	F	p
Regression	4.656	2	2.328	42.876	.000
Residual	.016	45	.002		
Total	2.552	47	.054		

Variables in regression equation						
Model	R	B	SE	Beta	t	P
Constant	-	-.200	.612		-.764	.449
Self-efficacy	.634	.213	.116	.210	1.840	.072
Effort	.788	.240	.042	.651	5.685	.000

Note. Multiple R=.804 & R^2=.646

The Pearson correlation shows that the coefficient between PSA and self-efficacy was r=.978 and between PSA and effort was r=.975 showing that there is a strong positive linear correlation because the value is positive and very close to one. This means the data points should be clustered closely around a positively sloping regression line, indicating improved motivation is followed by improved problem-solving and vice versa.

The value of $F(2, 7)=153.14$ in the regression analysis indicates that the model significantly represents the relationship between problem-solving abilities and motivational components ($p<.001$). It is also indicated that about 98% of the variations in PSA of students is accounted for self-efficacy (SE) and effort (E). That is, they both separately affect PSA of IG. The regression equation that best approximates the relationship between PSA, self-efficacy and effort is expressed as $PSA=0.224(SE)+0.21(E)-0.1$, where SE means self-efficacy and E means effort.

From **Table 15**, the value of $F(2, 45)=42.876$, $p=.00$ indicates that the multiple regression significantly models the relationship between PSA and the components of motivation. The regression coefficient of determination $R^2=.646$ indicates that 64.4% of the variation in PSA is accounted for by self-efficacy and effort. The regression equation that best approximates the relationship between PSA, self-efficacy, and effort is expressed as PSA=.240(SE)+.213(E)+.2.

These findings are supported by scholars such as Song (2005), who concluded that effort is one of the components that enables students to engage in the process of problem-solving. Under appropriate conditions, motivation contributes to the ability of students to solve problems (Weith & Burns, 2005). Problem-solving is a motivated process and is determined by human motivations and needs (Güss et al., 2017).

CONCLUSION

Based on the statistical analyses and the findings, it can be concluded that students who received instruction with GSP were more self-efficacious and engaged in a given geometry task and were better motivated than students who received traditional paper-pencil instruction. Likewise, motivation has a significant effect on PSA, especially on lower and medium-achieving students, to a greater extent than those who belong to the lower achiever group. These indicate that motivation and problem-solving are interrelated, one contributing to the other. Therefore, instruction supported with GSP is very useful to enhance students' motivation and problem-solving abilities. However, this study was limited only to two groups that could cause an internal validity threat. Future research is recommended as to why the intervention could not contribute to the HA group.

Recommendations

From the findings of this study, the following recommendations are forwarded.

1. School teachers and other concerned bodies need to give emphasis to instructional approaches such as the use of GSP, since it improves students' motivation and problem-solving abilities.
2. As achiever level increased, the contribution of GSP mediated instruction on motivation and PSA decreased. This needs further study since that will help design of instruction.

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