Geometry Competencies of High School Students: Basis for an Intervention Program

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ABSTRACT

The spiral progression approach builds on students' prior knowledge and skills and highlights the importance of learning pre-requisite concepts. This study aimed to determine the competencies in the Grade 7 and Grade 8 topics of the Grade 9 students in a junior high school in Agusan del Sur, Philippines as basis for an intervention program. Achievement test based on the Curriculum Guide of the Department of Education for Grade 7 Geometry and Grade 8 Geometry topics was administered to 316 respondents identified using stratified random sampling. Frequency and percentage were used to describe their profile (sex, and program enrolled-in); mean percentage score to determine their least learned competencies; and test concerning means (alpha = 0.05) to determine the influence of their profile in the least learned competencies. Findings revealed that majority of the respondents were females enrolled in the General Curriculum Heterogeneous Classes. The least learned topics in Grades 7 and 8 Geometry were Angle Properties and Parallel Lines, Inequalities in Triangles, and Parallelism and Perpendicularity. In Parallelism and Perpendicularity, females scored significantly higher than males. Significant difference was also evident among the mean scores of the respondents from the different programs for both Angle Properties and Parallel Lines, and Parallelism and Perpendicularity with the Science, Technology and Engineering outperforming the other programs. The findings imply the respondents' least learned competencies are influenced by the variation of their profile. An intervention program for the Grade 9 students is needed in the identified least learned competencies considering their sex, and program enrolled in.

Keywords: Competencies, Geometry, Intervention Program, High School Students

INTRODUCTION

Industrial Revolution (IR) 4.0 marks a significant shift in the global economy that is characterized by the seamless integration of advanced technologies into various industries. Its emergence is a result of the continuous technological developments that addressed many modern technologies (Moloi & Marwala, 2023; Alfaisal, 2024). In this age of rapid technological innovation, people need to have a certain set of skills that are both relevant and adaptive in order to not only survive, but thrive. As such, it is imperative that people develop competencies that are in line with evolving technologies. World Economic Forum (2016) emphasized that creativity will become one of the top three skills workers will need. With the avalanche of new products, new technologies and new ways of working, workers are going to have to become more creative in order to benefit from these changes.

Learning mathematics is viewed to develop students' critical and creative thinking. Through this, students can become individuals who are trained in their way of thinking, creative, independent, and have problem-solving abilities which are very useful in social life and in the context of IR 4.0 (Siswanto, et. al, 2022). In Geometry to be specific, students can train logical, systematic and creative thinking skills as this field of mathematics examines shapes, positions, and spatial properties (Fajriah, 2015). Furthermore, Mohamed & Kandeel (2023) mentioned that acquiring and developing spatial skills among students play an important role in learning mathematics and what they need for logical thinking and building relationships between different data.

However, there are issues and challenges in the learning of Geometry concepts among students. Jabahab (2014) identified geometry competencies to be among the ones where students have low mastery in Grade 7 mathematics. Meing Lie and Harun (2010) mentioned that low mastery level in Geometry is due to the lack of thinking skills and low understanding among students. Similarly, Adolphus (2011) determined that one factor that is responsible for the difficulty in the teaching and learning of geometry in secondary schools in Nigeria is the students' poor foundation in mathematics.

In the Philippines, the K to 12 Basic Education Curriculum employs a spiral progression approach. This approach builds on students' prior knowledge and skills to allow gradual mastery from one grade level to the next (Department of Education, 2013; Corpuz, 2014). According to schema theory, prior knowledge is a critical factor in forming a new cognitive schema to gain new knowledge. This suggests that what has been previously learned is a paramount factor in any meaningful learning to occur. As such, it is necessary both for the learner to hold some relevant prior knowledge, and for the teacher to make the connection to help the learner recognize its relevance (Bartlett, 1995; Rivas, 2007).

Assessment determines whether or not the goals of education are being met, thus an integral part of instruction. It provides insight to the teacher as to the instructional needs of the students for the lessons which are pre-requisite to learning the advance concepts (Wiggins, 2012). To successfully help the students master the concepts, teachers need to know not only where a child is functioning now and where that child will be tomorrow, but also how best to assist that child in mastering more advanced skills and concepts (Tools of the Mind, 2015).

As prescribed in the curriculum guide for Grade 9 Mathematics, geometric topics Quadrilaterals, Similarity, and Triangle Trigonometry are to be covered in the third quarter (K to 12 Mathematics Curriculum Guide, 2013). Given the spiral progression curriculum, performance of students in these topics depends on a great deal on their mastery of the pre-requisite lessons. Thus, it is important that geometry competencies of the Grade 9 students on the Grade 7 and 8 topics are assessed. The Grade 7 Geometry topics include Angle Properties and Parallel Lines; and Basic Properties of Simple Shapes. On the other hand, Grade 8 Geometry lessons are Reasoning; Triangle Congruence; Inequalities in Triangles; and Parallelism and Perpendicularity.

The National Achievement Test observes the following interpretation of the mean percentage scores (MPS): 96% - 100% means *mastered*; 86% - 95% means closely *approximating mastery*; 66% - 85% means *moving towards mastery*; 35% - 65% means *average mastery*; 16% - 34% means *low mastery*; 5% - 15% means *very low mastery*; and 0% - 4% means *absolutely no mastery* (Fernandez, 2013). With this, an MPS of below 35% for certain topics might be considered as areas where learners would benefit from an intervention program.

According to National Council of Teachers of Mathematics (2007), an intervention program is a structured plan for providing instructional materials and activities to support students' learning. This study served as a diagnostic assessment and provided basis for instructional actions – the design of an intervention program for Grade 9 students which will address the least learned Grade 7 and Grade 8 geometry competencies. These competencies in geometry of the students may be influenced by their profile – sex and program enrolled in. Thus, providing another basis in the crafting of the program.

A number of studies have verified the influence of sex on math achievement of students. Hence, it is crucial for educators and researchers to pay attention to sex differences in the design of mathematics instruction (Achor, et. al, 2010). One research is that of Erdogan, et. al (2011) where they looked into the gender differences in geometry and mathematics achievement and found out that there were significant gender differences on both mathematics achievement and geometry achievement with women achieved significantly higher than men. On the other hand, Cajindos (2013) pointed out in her study that student enrolled in the different degree programs have differences in performance in Trigonometry. Such finding implies differences in the Geometry competencies of students belonging to different programs.

Research Questions

1. What is the profile of the Grade 9 Mathematics students in terms of sex and program enrolled-in?

2. What are the least learned competencies of the students in the Grade 7 and Grade 8 Geometry?

3. Is there a significant difference in the mean scores of the students' least learned competencies when grouped according to their profile?

4. What intervention program can be developed to address the least learned competencies?

METHODOLOGY

This study utilized the descriptive method using the assessment technique. The study was conducted in a large secondary school in Agusan del Sur, Philippines. Academic programs of the school include Science, Technology, Engineering (STE); Strengthened Technical Vocational Education Program (STVEP); Special Program in the Arts (SPA); Special Program in Sports (SPS); and General Curriculum with Crack Sections and Heterogeneous Sections. The study involved the 316 Grade 9 students under the different programs or classes identified using stratified random sampling. Table 1 presents the distribution of population and sample of the study.

Table 1. Distribution of Population and Sample of the Study

Programs	Sections	Population		Sample
		No. of Students	Total	
Science, Technology, Engineering (STE)	Section L	42	128	38
	Section D	43		
	Section M	43		
Strengthened Technical Vocational Education Program (STVEP)	Section J	44	86	35
	Section A	42		
Special Program in the Arts (SPA)	Section O	48	93	38
	Section G	45		
Special Program in Sports (SPS)	Section A	48	94	34
	Section G	46		
General Curriculum Crack Sections	Section M	50	148	46
	Section T	49		
	Section D	49		
General Curriculum Heterogeneous Sections	Section M	87	419	125
	Section S	84		
	Section L	81		
	Section C	87		
	Section D	80		
Total			968	316

The instrument used in this study was an Achievement Test in Geometry for Grade 7 and Grade 8 Geometry topics developed by the researcher. The achievement test is composed of 50 items. All the items are multiple-choice questions – four choices with one correct answer except for an item about construction. The items were distributed among the Geometry topics in Grade 7 and Grade 8 as specified in the curriculum guide. The desired standards and competencies expected for the Grade level were considered in framing the questions. There were 17 items taken from Grade 7 Geometry topics and 33 items from Grade 8 Geometry topics. The items were constructed following the DepEd Order No. 73, s. 2012 which is on the guidelines on the assessment of learning outcomes under the K to 12 Basic Education Curriculum. Based on the said document, learning outcomes are defined by level: Knowledge (K); Process/Skill (P); Understanding (U); and Product / Performances (P). Furthermore, the levels shall be given corresponding percentage weights as 15%, 25%, 30%, and 30%, respectively. But since this study used a test questionnaire, the researcher dropped the product and performance level of learning outcomes in designing the Assessment Matrix and its corresponding weight was proportionally distributed among the other levels of assessment.

Angle Properties and Parallel Lines; and Basic Properties of Simple Shapes were the coverage for Grade 7 while Reasoning; Triangle Congruence; Inequalities in Triangles; and Parallelism and Perpendicularity were the topics for Grade 8. In deciding the number of items to be allocated for each of the competencies, the researcher referred on the suggested number of hours for the delivery of the said topics as stipulated in the respective curriculum guides of Grade 7 and Grade 8 Mathematics. The number of items given for a topic was proportional to the length of the teaching time. The items were distributed among the levels of learning outcomes based on what the competency intended to measure.

The researcher-developed achievement test had undergone content validation by experts and was pilot-tested. Item analysis was also done. Reliability of the achievement test was established by test-retest. The Pearson r was calculated and was found to be $r=0.806$, thus the test has good reliability and is highly stable. The administration of the achievement test was undertaken for one day. The achievement test which is good for 1 hour was conducted in the respective classrooms of the respondents.

To facilitate statistical analysis, the researcher used the frequency and percentage to describe the profile of the respondents classified according to sex and program enrolled-in; and mean score and mean percentage score to determine the competency level of the respondents in the Grade 7 and Grade 8 Geometry topics. The equivalent verbal description of the mean percentage score is determined using the scale and descriptive rating observed in the National Achievement Test. Analysis of Variance (ANOVA) was employed to determine if significant difference exists in the mean scores of the respondents' least learned competencies when grouped according to program enrolled in. If significant difference exists, appropriate post hoc test was utilized. The z-test on Independent Samples was utilized to determine if significant difference exists in the mean scores of the respondents' least learned competencies when grouped according to sex.

RESULTS AND DISCUSSION

Profile of the Respondents

The profile of the respondents according to sex revealed that of 316 respondents, females (184 or 58.23%) outnumber males (132 or 41.77%). Grouped according to program enrolled, students under the General Curriculum Heterogeneous Sections comprised the most number of respondents with 125 (39.56%). Least number of respondents comes from STVEP and SPS. STVEP has 35 (11.07%) of the respondents while SPS has 34 (10.76%). Such distribution of respondents is due to the fact that the SPA and STVEP are two of the three academic programs with only two sections, thus only lesser number of students. On the other hand, having General Curriculum Heterogeneous Sections as the group with the highest number of respondents only reflects that such program has the most number of sections in all the grade levels. This trend is not only true to the research locale but in other public high schools as well. Public high schools in general provide the Basic Education General Curriculum with heterogeneous classes and only offer special programs when they have the capability of offering them and/ or have enough number of students qualified for admission to such programs.

Least Learned Competencies in Geometry

The competency level of the respondents in Grade 7 and Grade 8 Geometry with emphasis on their least learned competencies are determined. The identified competencies are grouped based on topic and grade level. The respondents' corresponding mean scores, mean percentage scores (MPS), and verbal descriptions for each competency are presented in Table 2.

Table 2. Competency Level of the Respondents in the Geometry Topics

Topics	Items	Mean Score	MPS	Verbal Description
Grade 7				
Angle Properties and Parallel Lines	7	2.30	32.86%	Low Mastery
Basic Properties of Simple Shapes	10	3.58	35.80%	Average Mastery
Grade 8				
Reasoning	8	3.06	38.25 %	Average Mastery
Triangle Congruence	17	6.42	37.76 %	Average Mastery
Inequalities in Triangles	5	1.42	28.40 %	Low Mastery
Parallelism and Perpendicularity	3	1.01	33.67 %	Low Mastery
N = 316				

In Grade 7 Geometry, the respondents performed better in Basic Properties of Simple Shapes than in Angle Properties and Parallel Lines. The latter obtained an MPS equivalent to an average mastery level while the former is that of low mastery level. For Grade 8 Geometry, the respondents got the highest MPS in Reasoning and Triangle Congruence – both fall under an average level of mastery. In contrast, Inequalities in Triangles obtained the lowest MPS equivalent to a low mastery level.

In determining the least learned competencies, the competencies where the respondents obtained an MPS of below 35% or a verbal description of low mastery were identified. The said competencies are Angle Properties and Parallel Lines, Inequalities in Triangles, and Parallelism and Perpendicularity. Among the least learned competencies, Inequalities in Triangles got the lowest MPS. These findings support what Jabahab (2014) had noted in his study that Angle Properties and Parallel Lines belongs to the competencies in Grade 7 Geometry where students have low mastery. The topics Inequalities in Triangles; and Parallelism and Perpendicularity as the least learned competencies for Grade 8 Geometry may be attributed to the fact that these lessons are to be covered in fourth grading. During this part of the school year, the teachers are usually coping with the lessons that are yet to be covered thereby failing to provide deepening activities or even failing to cover these lessons.

Significant Difference on the Least Learned Competencies

According to Respondents' Profile Sex

In all the identified least learned competencies for Grade 7 and Grade 8 Geometry – Angle Properties and Parallel Lines, Inequalities in Triangles, and Parallelism and Perpendicularity, males obtained an MPS equivalent low mastery level (31.43 %, 28.80 %, and 28.33%, respectively). The same is true for females (33.86 %, 28.20 %) except for Parallelism and Perpendicularity competency where they got an MPS (37.33 %) equivalent to an average mastery. Both sexes have the lowest MPS in Inequalities in Triangles. In the three identified least learned competencies, females got a higher mean score in Angle Properties and Parallel Lines and in Parallelism and Perpendicularity. On the other hand, males attained higher mean score in Inequalities in Triangles. z-test for

independent samples was performed to determine if significant difference existed in the mean scores of the sexes. The result is shown in Table 3.

Table 3. z-test on Independent Samples for the Least Learned Competencies Classified by Topic of the Respondents Grouped According to Sex

Topics	Computed z-value	Conclusion
Angle Properties and Parallel Lines	-0.865	Not Significant
Inequalities in Triangles	0.177	Not Significant
Parallelism and Perpendicularity	-2.525	Significant
Critical Region at alpha = 0.05: $z < -1.96$ and $z > 1.96$		

The test showed that there is no significant difference in the mean scores of the male and female respondents in Angle Properties and Parallel Lines and in Inequalities in Triangles. The results further revealed that significant difference existed in the mean scores of the male and female for Parallelism and Perpendicularity with females scoring significantly higher. This finding support that of Erdogan, et. al (2011) that there are significant gender differences on both mathematics achievement and geometry achievement with women achieved significantly higher than men. Furthermore, this implies that female students do not anymore need an intervention program for Parallelism and Perpendicularity.

Program Enrolled In

Out of the six programs, the STE obtained an MPS (78.57%) equivalent to a moving towards mastery level for the Angle Properties and Parallel Lines while the rest of the groups fell under low mastery level (<35.00%). All the programs fell under low mastery level for the Inequalities in Triangles (<35.00%). Furthermore, in Parallelism and Perpendicularity, STE lead the groups followed by STVEP with an MPS (59.67%, 37.00%) equivalent to an average mastery. SPA, SPS, Crack Sections and Heterogeneous Sections all attained an MPS equivalent to low mastery. To determine if a significant difference exists in the mean scores of least learned competencies when respondents are grouped according to the program they are enrolled in, analysis of variance was performed. Table 5 presents its results which revealed that there is a significant difference in the mean scores of the respondents when grouped according to program enrolled in for Angle Properties and Parallel Lines. Such significant difference also exists in Parallelism and Perpendicularity.

Table 5. Analysis of Variance for the Mean Scores in the Least Learned Competencies Classified by Topic of the Respondents Grouped in Terms of Program Enrolled In

Sources of Variation	Dependent	F	P-value	Conclusion
Program Enrolled In	Angle Properties and Parallel Lines	52.174	0.000	Significant
	Inequalities in Triangles	0.818	0.538	Not Significant
	Parallelism and Perpendicularity	6.545	0.000	Significant
F-critical at 0.05 = 2.243				

Post hoc analysis for Angle Properties and Parallel Lines revealed that the mean score of the respondents under STE differ significantly to the mean score of the respondents under the five other programs (p=0.00). Furthermore, there is no significant difference in the mean score of the respondents under STVEP, SPA, SPS, Crack Sections, and Heterogeneous Sections. This means that the STE group outperformed the rest of the other programs in the Angle Properties and Parallel Lines. It can be recalled that the mean score of the STE in this

competency is equivalent to moving towards mastery. Furthermore, the students under this program are admitted based on their inclination towards sciences and mathematics, thus explaining the significant difference in their mean scores from the other programs. Hence, the STE group does not anymore need an intervention for the topic Angle Properties and Parallel Lines.

On the other hand, post hoc analysis on the mean scores of the respondents for Parallelism and Perpendicularity reported that the mean scores of the SPS, Heterogeneous Sections, SPA, Crack Sections, and STVEP do not have a significant difference while the mean score of STE differ significantly to the rest of the programs. This means that STE outperformed the different groups in Parallelism and Perpendicularity. This implies that STVEP together with the other groups need an intervention program for Parallelism and Perpendicularity while the STE group does not anymore need an intervention in the mentioned topic.

The foregoing findings reveal that significant difference exists in the mean scores of the respondents when grouped according to program in Angle Properties and Parallel Lines, and Parallelism and Perpendicularity. In these competencies, STE has performed better than the other programs. This can be attributed to the group being the cream of the crop among the sections or programs. It supports the findings of the study of Cajindos (2013) that students enrolled in the different degree programs have differences in performance in mathematics.

Intervention Program to Address the Least Learned Competencies

Generally, the students needed an intervention program in Angle Properties and Parallel Lines, Inequalities in Triangles, and Parallelism and Perpendicularity. Based on the earlier findings, both male and female students needed intervention in Angle Properties and Parallel Lines. Furthermore, all programs except STE had this as least learned competency. This implies that an intervention program on this competency should be designed for all students who are not under STE. To determine the specific sub-topics where the mentioned groups need intervention program, the competency level for each of the learning competencies under Angle Properties and Parallel Lines were determined and presented in Table 6. The respondents obtained an average mastery on the learning competencies 1, 2, and 3 while a low mastery level in the rest of the other competencies. Therefore, the content of the intervention program that should be designed would include angle pairs, parallel and perpendicular lines, angles formed by parallel lines cut by a transversal; and segment bisector and angle bisector.

Table 6. Competency Level in the Components of Angle Properties and Parallel Lines

Learning Competencies	Items	Mean	MPS	Verbal Description
1. represents point, line and plane using concrete and pictorial models.	2	0.84	42.00%	Average Mastery
2. illustrates subsets of a line.				
3. classifies the different kinds of angles.				
4. derives relationships of geometric figures using measurements and by inductive reasoning; supplementary angles, complementary angles, congruent angles, vertical angles, adjacent angles, linear pairs, perpendicular lines, and parallel lines.	2	0.49	24.50%	Low Mastery
5. derives relationships among angles formed by parallel lines cut by a transversal using measurement	2	0.66	33.00%	Low Mastery
6. uses a compass and straightedge to bisect line segments and angles & construct perpendiculars	1	0.31	31.00%	Low Mastery
N = 316				

Both male and female, and all programs needed intervention in the Inequalities in Triangles, thus, all students. To determine the specific sub-topics where the students need intervention program, the competency level for each of the learning competencies under Inequalities in Triangles were determined and shown in Table 7. All the learning competencies fell under low mastery and therefore, the topics Triangle Inequality Theorems, Exterior Angle Inequality Theorem and Hinge Theorem should be included in the content of the intervention program.

Table 7. Competency Level in the Components of Inequalities in Triangles

Learning Competencies	Items	Mean	MPS	Verbal Description
1. illustrates theorems on triangle inequalities (Exterior Angle Inequality Theorem, Triangle Inequality Theorem, Hinge Theorem).	1	0.29	29.00%	Low Mastery
2. applies theorems on triangle inequalities.	2	0.63	31.50%	Low Mastery
3. proves inequalities in a triangle.	2	0.50	0.25%	Low Mastery
N = 316				

Between males and females, only males need intervention in Parallelism and Perpendicularity. Also, all programs except STE need intervention in the said competency. This means that an intervention program on Parallelism and Perpendicularity should be designed for all male students who are not enrolled in STE. The specific sub-topics where the students need intervention under the Parallelism and Perpendicularity were determined and shown in Table 8. The respondents obtained a low mastery level in proving properties of parallel lines cut by a transversal while an average mastery level is achieved for determining the conditions for parallelism or perpendicularity of lines. This indicates that the topic on proving properties of parallel lines cut by a transversal should be included in the intervention program.

Table 8. Competency Level in the Components of Inequalities in Triangles

Learning Competencies	Items	Mean	MPS	Verbal Description
1. proves properties of parallel lines cut by a transversal.	1	0.26	26.00%	Low Mastery
2. determines the conditions under which lines and segments are parallel or perpendicular.	2	0.75	37.50%	Average Mastery
N = 316				

In planning the activities in the program, the participants were considered. The first consideration in designing the activities is the program where the students are enrolled in. On the effective strategies for teaching students with difficulties in Mathematics, systematic and explicit instruction has consistently strong effects on improving students' performance. Explicit instruction involves components such as clear modeling of the solution specific to the problem, thinking the specific steps aloud during modeling, presenting multiple examples of the problem and applying the solution to the problems, and providing immediate corrective feedback to the students on their accuracy (Jayanthi, Gersten, and Baker, 2008; National Council of Teachers of Mathematics, 2007). With the aforementioned premise, the researcher has designed lesson plans for the intervention program using direct or explicit instruction with varied approaches. Cooperative learning is also utilized depending on the content and the recipients of the intervention program.

CONCLUSIONS

The topics on Angle Properties and Parallel Lines is the least learned competency for Grade 7 Geometry while for Grade 8 Geometry are Inequalities in Triangles, and Parallelism and Perpendicularity. These are the topics in which Grade 9 students needed to be helped at for them to operate in the advanced Geometry concepts for their grade level with less difficulty. Mastery in the said topics would help them be able to investigate, analyze, and solve problems involving parallelograms and triangle similarity; and to apply the concepts of trigonometric ratios to formulate and solve real-life problems. Since the least learned competencies of the students vary as influenced by their profile, the intervention program that is designed to address the least learned competencies must consider sex and program the students are enrolled in.

RECOMMENDATIONS

Teachers should provide emphasis in the identified least learned competencies in their discussion of Geometry topics. Better performance will be achieved by students if they will be able to relate and make connections with the pre-requisite concepts of the lessons. Therefore, students should see to it that they have acquired the foundational skills. School administrators should design intervention program that are based on the clearly identified least learned competencies of the students. Department heads should make it a practice of diagnosing the level of mastery of the students in the pre-requisite concepts before introducing advanced topics so that least learned competencies will be catered. A study on the least learned competencies for the other strands of Mathematics Curriculum may be conducted. Further study on the least learned competencies on Geometry and the effect of other variables in the performance of students in Geometry may be done

Compliance with Ethical Standards

The authors hereby declare that the research activities undertaken in this study were conducted in full compliance with the highest ethical standards. Informed consent were obtained from the participants with freedom to withdraw from the study at any time, their anonymity maintained, and their well-being safeguarded. There is no conflict of interest in the conduct of the study, plagiarism was strictly avoided, and no bias in the interpretation of the findings. The results were used purely for research.

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