J. Myanmar Acad. Arts Sci. 2020 **Vol. XVIII. No.9C**

A STUDY OF THE RELATIONSHIP BETWEEN STUDENTS' SPATIAL ABILITY AND THEIR GEOMETRICAL PERFORMANCE IN MATHEMATICS AT THE MIDDLE SCHOOL LEVEL

Phyo Khin Khin[1] and Wai Wai Oo[2]

Abstract

The main purpose of this research is to study the correlation between students' spatial ability and their geometrical performance in mathematics at the middle school level. Especially, this study aims to study students' spatial ability in terms of visualization, spatial relation, closure speed, flexibility of closure and perceptual speed. A descriptive research design was used for this study. Four townships were randomly selected from four districts in Yangon Region. Two high schools were chosen in each township. A total of eight basic education high schools were included in this study. The participants in this study were (600) Grade Seven students. As the research instruments, a test for spatial ability and a test for geometrical performance test were used. To obtain the reliability of these instruments, a pilot test was administered. The internal consistency (Cronbach's Alpha) of the test for students' spatial ability was (.682) and the test for students' geometrical performance was (.625). In order to address the research questions, a descriptive statistics (percentage) and Pearson product-moment correlation were used. The percentage of low, moderate and high levels of students' spatial ability were 12.67% (N=76), 75% (N=450) and 12.33% (N=74) respectively. The percentage of low, moderate and high levels of students' geometrical performance were 7% (N=42), 84.17% (N=505) and 8.83% (N=53) respectively. So, the students' spatial ability and geometrical performance were found the highest in moderate level. According to the Pearson product-moment correlation result, there was a positive correlation between students' spatial ability and their geometrical performance ($r = .685$, $p < .01$). This means that a high level of students' spatial ability will bring about a high level of their geometrical performance in mathematics.

Keywords: spatial ability, spatial visualization, spatial relation, closure speed, flexibility of closure, perceptual speed, geometry, performance

Introduction

Nowadays, education plays a critical role in the development of any nation since it is fundamental to the expended human capabilities which lie at the heart of the meaning of development. Mathematics is an indispensable part of education. It is a very useful subject for many vocations and higher specialized courses of learning. The ability to visualize mathematical relationships is an essential part of knowledge of mathematics and communicating ideas about mathematics. Especially, spatial ability is one of the necessary factors for achievement of mathematics as it helps to recognize symbols such as numbers and operation signs or visualize mental images. Spatial ability is the capacity to understand and remember the spatial relations among objects. Spatial visualization is necessary for interpreting, understanding, and appreciating the geometric world (NCTM, 1989). Students with strong spatial ability can imagine a shape from different view points, or they can easily comprehend drawings by visualizing spatial patterns quickly and solve problems by thinking in different ways. This study focused on the correlation between students' spatial ability and geometrical performance in mathematics and it is also essential to improve mathematics teaching and learning at the middle school level.

[1] Assistant Lecture, Methodology Department, Yankin Education College
[2] Dr, Associate Professor and Head of Department of Methodology, Sagaing University of Education

Purposes of the Study

The main purpose of this research is to study the relationship between students' spatial ability and their geometrical performance in mathematics at the middle school level. The specific purposes of this research are as follows:

- To investigate students' spatial ability in the selected schools
- To assess students' geometrical performance in mathematics in the selected schools
- To explore the relationship between students' spatial ability and their geometrical performance in mathematics
- To give suggestions for improving spatial ability in mathematics at the middle school level

Research Questions

1. To what extent do students possess spatial ability?
2. To what extent do students perform geometrical tasks in mathematics?
3. Is there any significant relationship between students' spatial ability and their geometrical performance in mathematics?

Review of Related Literature

Computation is a vital component of mathematics. But, students need to focus on more than just accuracy in calculation. The cognitive abilities like numerical reasoning ability, sequential ability and spatial ability together comprise as necessary factors for achievement of mathematics. Teaching mathematics is not only for problem-solving but also for enhancing higher cognitive abilities. The ability to make mental representations of number and space is one of the most critical cognitive abilities for mathematics learning. Spatial aspect of mathematics is one of the important mental representations for children. Mental representations include the characteristics of objects, relative positions of objects, rotations of objects as the same object, composition and decomposition of objects, recognition of symbols, spatial orientation, and interpretation of drawings and even some concepts of time.

Spatial Ability: It plays an important role in ones’ lives and it is used unconsciously. Spatial perception accompanies man from birth. Its development is connected not only with the cognitive processes but also with education. According to Linn and Peterson (1985), spatial ability refers to skill in representing, transforming, generating, and recalling symbolic, non-linguistic information. It is not a unitary construct, but it is a combination of sub-skills such as using maps, solving geometry questions and recognizing two dimensional representations of three-dimensional objects.

Visualization in mathematics is the kind of reasoning activity based on the use of visual and spatial elements, either mental or physical, performed to solve problems or prove properties. According to Olkum (2003), spatial ability is used for mental the abilities related to the use of space. Spatial ability has been an area of study for decades as a collection of cognitive skills that enable one interact with his environment. For academic and vocational training programs, spatial ability tests correlate with course grades in mechanical drawings, shop courses, art, mathematics, physics and mechanics. High levels of spatial ability have frequently been linked to creativity, not only in the arts, but in science and mathematics.

Classifications and Subdivisions of Spatial Ability: McGee (1979) stated that spatial ability has two of principal factors; spatial visualization and spatial orientation. Spatial visualization refers to the ability to mentally rotate, manipulate and twist two or three dimensional stimulus objects. Spatial orientation involves the comprehension of the arrangement of elements within a visual stimulus pattern. Early research made by Linn and Petersen (1985), they classified spatial test into three categories as spatial perception, spatial visualization and mental rotation or spatial manipulation. They defined spatial perception as the ability to determine spatial relation despite distracting information; spatial visualization as the ability to manipulate complex spatial information when several stages are needed to produce correct solution and mental rotation as the ability to rotate, in imagination quickly or accurately two or three dimensional figures.

Lohman (1979) identified two main aspects of spatial ability; spatial orientation and spatial visualization. Spatial orientation involved the ability to imagine how a given object or sets of objects would appear from a spatial perspective different form that in which the objects are shown. Lohman, Pelegrino, Alderton, and Regian (1987) proposed the existence of (10) significant subdivisions of spatial abilities. Table 1 lists these (10) distinct and minor spatial sub-factors.

Table 1 Lists of Spatial Subdivisions

Factor Label	Factor Name	Test that define the factor
Vz	Visualization	Paper Folding, Paper Form board, Surface Development
SO	Spatial Orientation	Card Rotation, Cube Comparison, Water Level
CF	Flexibility of Closure	Embedded Figures, Hidden Figures, Copying, Hidden Patterns
SR	Speeded Rotation	Cards, Flags, Figures
SS	Spatial Scanning	Maze Tracing, Choosing a Path, Way Finding
PS	Perceptual Speed	Comparing Figures and Symbols
SI	Serial Integration	Successive Perception, Picture Identification
CS	Closure Speed	Gestalt Completion, Concealed words
VM	Visual Memory	Location memory, Memory for Design
K	Kinesthetic	Hands

Source: From Lohman, 1987.

Carroll's Five Major Factors of Spatial Ability: Carroll (1993) analyzed more than (140)datasets and detected five major clusters: Visualization (Vz), Spatial Relations (SR), Closure Speed (CS), Flexibility of Closure (CF), and Perceptual Speed (PS).Carroll's definition of Vz factor does not differ from than that of other researchers mentioned. Spatial Relations factor (SR) can be considered as another name for the Speeded Rotation factor defined by Lohman (1987) for three dimensional objects. Closure Speed (CS) factor concerns individual differences in ability to access spatial representations in long-term memory when incomplete or obscured cues to those representations are presented. The subjects are not told what to look for in a given representation.

Flexibility of closure (CF) is the ability to identify a visual figure or pattern embedded in a complex distracting or disguised visual pattern or array, when knowing in advance what the object is. Perceptual Speed (PS) factor is characterized by the speed in finding a given configuration in a mess of distracting material. The task may include comparing pairs of items, locating a unique item in a group of identical items, or locating a visual pattern in an extended visual field. According to French (1951), cited in Carroll, (1993), perceptual speed is the speed in scanning figures, or symbols and comparing them or carrying out other very simple tasks involving visual perception.

Spatial Ability and Mathematics Education: Children's early mathematics ability is an important predictive factor to later mathematics achievement. So, how to promote children's early mathematics competency is of critical importance. It is a save report that there is a positive correlation between spatial ability and mathematics achievement (Battista, 1990). Furthermore, according to Van Garderen (2003), spatial ability is a significant factor in specific areas of mathematics such as geometry and in particular complex problems.The National Council of Teachers of Mathematics (2000) emphasize the importance of spatial abilities in mathematics education and recommend that mathematics instruction programs should pay attention to geometry and spatial sense so that all students use visualization and spatial reasoning to solve problems both within and outside of mathematics. Therefore, spatial sense or imagery is an important part of geometry and mathematics learning.

Spatial ability especially spatial visualization is an important component in solving many types of mathematics. Especially, the way to improve pupils' problem-solving ability is to encourage students to use imagery and visualization strategies. A creative problem solving is depending on combining spatial relations, classifications, transforming, and rotation and visualization activities together. So, many researchers supported that spatial ability is important to the development of mathematical thinking and mathematics education.

Spatial Sense and Geometric Reasoning: Geometry is a "network of concepts, ways of reasoning and representation systems" used to explore and analyze shape and space (Battista, 2007 cited in Walle et al., 2013). Geometry provides a rich context for learners to experience mathematical activity and the communication of this activity. Geometry is an important domain of purely mathematical activity.

It is useful to think about the geometry objectives in terms of two related frameworks: (1) spatial sense and geometric reasoning and (2) the specific geometric content. The first frame has to do with the way students think and reason about shape and space. The second framework is content in the more traditional sense _ knowing about symmetry, triangles, parallel lines, and so forth (NCTM, 2000). Spatial sense can be defined as the intuition about shapes and the relationships between shapes and is considered a core area of mathematical study, like number (Sarama & Clements, 2009, cited in Walle, et al., 2013). Spatial sense includes the ability to mentally visualize objects and spatial relationships to turn around in our mind. It includes a comfort with geometric description of objects and position. People with well-developed spatial sense appreciate geometric form in art, nature, and architecture and they use geometric ideas to describe and analyze their world. Mathematics instruction programmes should pay attention to geometry and spatial sense so that all students use visualization and spatial reasoning to solve problems both within and outside of mathematics.

Research Method

Research Design

The research design for this study was a descriptive research design, in which the researcher sought to determine whether and to what degree, a relationship exists between five variables (students' visualization, spatial relation, closure speed, flexibility of closure and perceptual speed) and geometrical performance in mathematics. In this study, the data were collected through a quantitative method. A quantitative method is a research technique that is used to gather quantitative data-information dealing with numbers and anything that is measurable (Gay & Airasian, 2003).

Sample of the Study

The total of (600) Grade Seven students were randomly selected from eight basic education high schools from four townships (Yankin, Dagon, Twantay and Mingalardon) in Yangon Region during (2017-2018) as participants for this study.

Instruments

In this study, a test for students' spatial ability and a test for measuring students' geometrical performance were used as the instruments. A test for students' spatial ability was mainly based on Carroll's five major factors of spatial ability (Visualization, Spatial Relation, Closure Speed, Flexibility of Closure and Perceptual Speed). A test for students' geometrical performance was constructed based on van Hiele's model of geometric thought.

Procedures

First, the related literature about the study was explored and then constructed the spatial ability test that is based on Carroll's five major factors and geometrical performance test that is based on the first three levels of Van Hiele's model of geometric thought. Expert review was conducted for the validation of the tests by five experienced mathematics teacher educators of Methodology Department in Yangon University of Education. After getting the validation, a pilot test was conducted with (50) Grade Seven students from B.E.H.S (3) Sanchaung in December, 2017. The data obtained from the pilot study was used to calculate Cronbach's alpha coefficient. The internal consistency of the test for spatial ability was (0.682) and the test for geometrical performance was (0.625). The real data collection was done in the first week of January 2018. After that, students' answer sheets for both spatial ability and geometrical performance were scored manually based on the marking scheme. All the data were organized in the computer data file. Then, the data were systematically analyzed by using the Statistical Package for the Social Science (SPSS 23) as it is widely used in quantitative research.

Research Findings

(1) Findings of Students' Visualization in Spatial Ability in the Selected Schools

Table 1 described the means of students' visualization in spatial ability in the selected schools.

Table 2 Means of Students' Visualization in Spatial Ability in the Selected Schools

School	No. of Student	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	6.37	1.514	3	10
BEHS (2) Yankin (S2)	75	7.03	1.414	5	10
BEHS (1) Dagon (S3)	75	6.88	1.506	3	10
BEHS (2) Dagon (S4)	75	6.69	1.355	5	10
BEHS (1) Twantay (S5)	75	**6.11**	1.921	2	10
BEHS (2) Twantay (S6)	75	6.81	1.343	5	9
BEHS (1) Mingalardon (S7)	75	6.93	1.446	5	10
BEHS (2) Mingalardon (S8)	75	**7.37**	1.292	5	10
Total / Average	**600**	**6.77**	**1.474**	**4.125**	**9.875**

According to the results, the lowest mean and the highest mean were (6.11) and (7.37) respectively. Therefore, students' visualization in Basic Education High School No. (1), Twantay was the lowest and students' visualization in Basic Education High School No.(2), Mingalardon was the highest among the selected schools. students' visualization in the selected schools (see Figure 1).

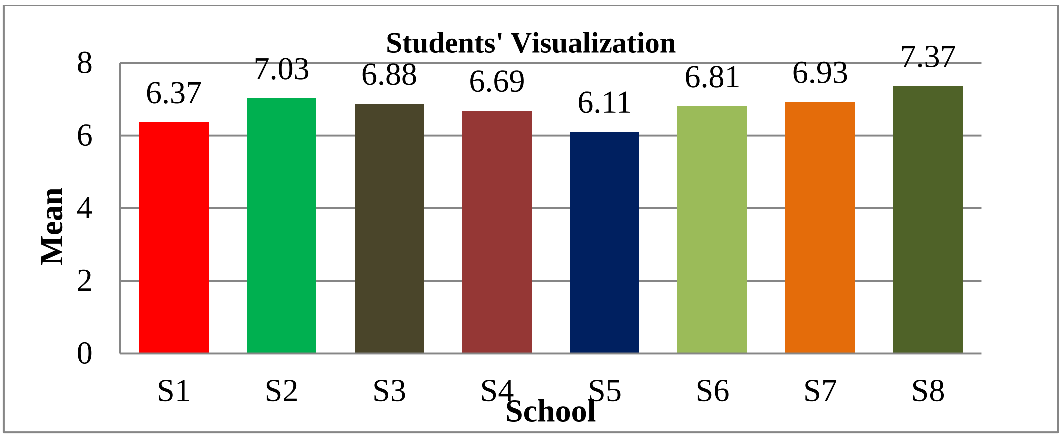

Figure 1 Comparison of Means of Students' Visualization in Spatial Ability in the Selected Schools

(2) Findings of Students' Spatial Relation in Spatial Ability in the Selected Schools

Table 3 described the means of students' spatial relation in spatial ability in the selected schools.

Table 3 Means of Students' Spatial Relation in Spatial Ability in the Selected Schools

School	No. of Student	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	5.08	1.136	4	8
BEHS (2) Yankin (S2)	75	5.63	1.292	3	9
BEHS (1) Dagon (S3)	75	5.67	1.446	4	9
BEHS (2) Dagon (S4)	75	5.09	1.210	3	9
BEHS (1) Twantay (S5)	75	**4.53**	1.119	2	8
BEHS (2) Twantay (S6)	75	4.87	1.143	4	8
BEHS (1) Mingalardon (S7)	75	5.71	1.440	4	10
BEHS (2) Mingalardon (S8)	75	**5.76**	1.364	4	9
Total / Average	**600**	**5.29**	**1.268**	**3**	**8.75**

According to the results, the lowest mean and the highest mean were (4.53) and (5.76) respectively. The students from Basic Education High School No.(1), Twantay have the lowest spatial relation and the students from Basic Education High School No.(2) Mingalardon have the highest spatial relation among the selected schools. Moreover, Figure 2 illustrated the comparison of the means of students' spatial relation in the selected schools.

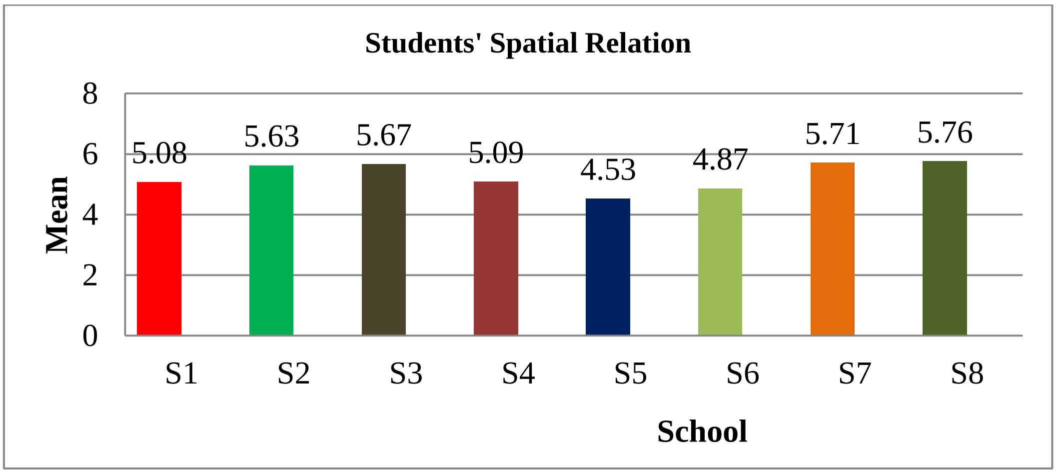

Figure 2 Comparison of Means of Students' Spatial Relation in Spatial Ability in the Selected School

(3) Findings of Students' Closure Speed in Spatial Ability in the Selected Schools

Table 4 described the means of students' closure speed in spatial ability in the selected schools.

School	No. of Student	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	6.51	1.554	3	9
BEHS (2) Yankin (S2)	75	6.87	1.735	3	10
BEHS (1) Dagon (S3)	75	6.84	1.748	3	10
BEHS (2) Dagon (S4)	75	6.85	1.768	3	10
BEHS (1) Twantay (S5)	75	6.52	1.727	3	10
BEHS (2) Twantay (S6)	75	**5.87**	1.571	2	9
BEHS (1) Mingalardon (S7)	75	6.56	1.862	3	10
BEHS (2) Mingalardon (S8)	75	**7.44**	1.233	4	10
Total / Average	**600**	**6.68**	**1.702**	**3**	**9.75**

Based on the results, the lowest mean and the highest mean were (5.87) and (7.44) respectively. The students from Basic Education High School No.(2) Twantay have the lowest closure speed while the students from Basic Education High School No.(2) Mingalardon have the highest closure speed among the selected schools (see Figure 3).

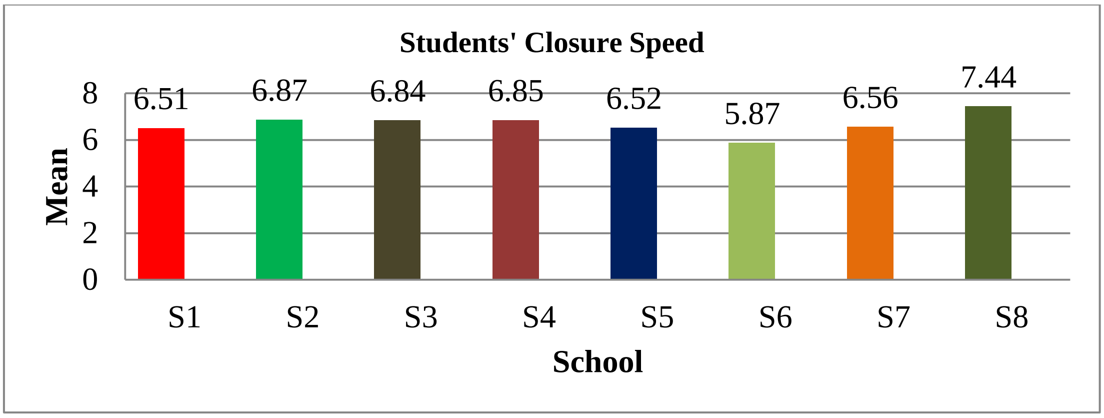

Figure 3 Comparison of Means of Students' Closure Speed in Spatial Ability in the Selected Schools

(4) Findings of Students' Flexibility of Closure in Spatial Ability in the Selected Schools

Table 5 described the means of students' flexibility of closure in spatial ability in the selected schools.

Table 4 Means of Students' Flexibility of Closure in Spatial Ability in the Selected Schools

School	No. of Student	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	5.07	1.742	1	9
BEHS (2) Yankin (S2)	75	4.51	1.455	2	8
BEHS (1) Dagon (S3)	75	4.69	1.365	2	8
BEHS (2) Dagon (S4)	75	4.69	1.507	2	8
BEHS (1) Twantay (S5)	75	**4.47**	1.388	2	7
BEHS (2) Twantay (S6)	75	4.68	1.629	1	8
BEHS (1) Mingalardon (S7)	75	5.05	1.793	2	10
BEHS (2) Mingalardon (S8)	75	**5.80**	1.433	3	9
Total / Average	**600**	**4.87**	**1.591**	**1.875**	**8.375**

Based on the results, the students who have the lowest flexibility of closure were from Basic Education High School No.(1) Twantay and the students who have the highest flexibility of closure were from Basic Education High School No.(2) Mingalardon respectively (see Figure 4).

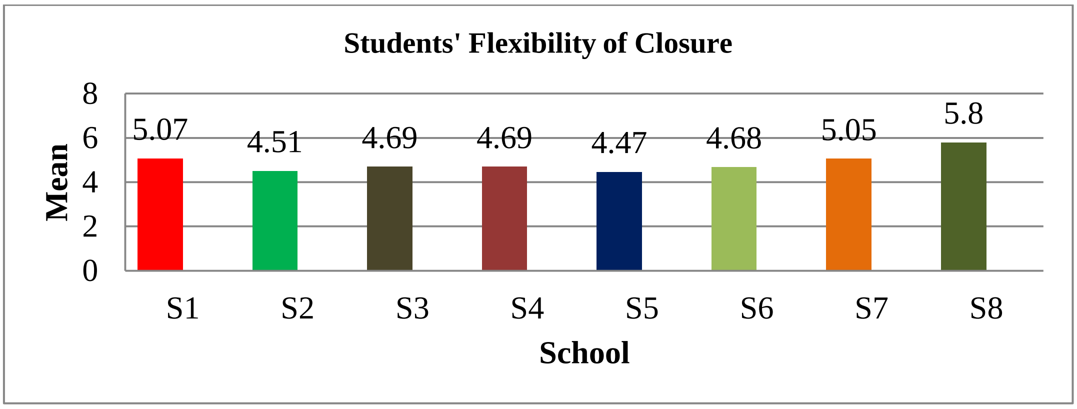

Figure 4 Comparison of Means of Students' Flexibility of Closure in Spatial Ability in the Selected Schools

(5) Findings of Students' Perceptual Speed in Spatial Ability in the Selected Schools

Table 6 Means of Students' Perceptual Speed in Spatial Ability in the Selected Schools

School	No. of Students	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	8.33	1.288	4	10
BEHS (2) Yankin (S2)	75	8.53	1.473	1	10
BEHS (1) Dagon (S3)	75	8.64	1.181	6	10
BEHS (2) Dagon (S4)	75	8.85	1.182	6	10
BEHS (1) Twantay (S5)	75	**8.04**	1.511	4	10
BEHS (2) Twantay (S6)	75	8.51	1.349	6	10
BEHS (1) Mingalardon (S7)	75	**9.07**	0.991	6	10
BEHS (2) Mingalardon (S8)	75	8.65	1.133	6	10
Total / Average	**600**	**8.58**	**1.300**	**4.875**	**10**

Based on the results, the lowest mean and the highest mean were (8.04) and (9.07) respectively. The students from Basic Education High School No.(1) Twantay have the lowest perceptual speed while the students from Basic Education High School No.(1) Mingalardon have the highest perceptual speed (see Figure 5).

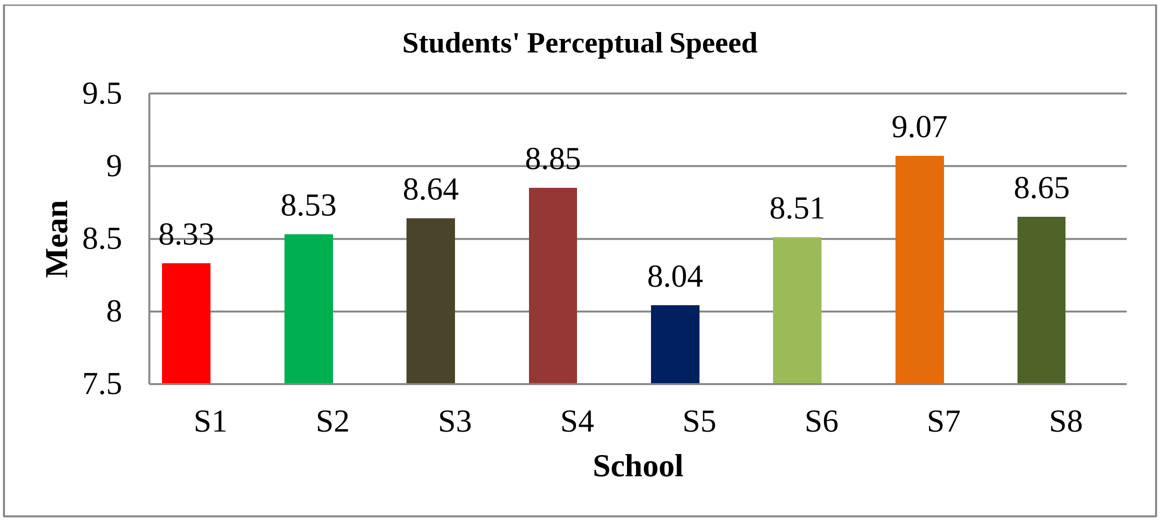

Figure 5 Comparison of Means of Students' Perceptual Speed in Spatial Ability in the Selected Schools

(6) Findings of Students' Spatial Ability in the Selected Schools

Table 6 described the means of students' spatial ability in the selected schools.

Table 7 Means of Students' Spatial Ability in the Selected Schools

School	No. of Student	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	31.35	3.981	22	40
BEHS (2) Yankin (S2)	75	32.43	4.205	25	42
BEHS (1) Dagon (S3)	75	32.91	4.765	23	43
BEHS (2) Dagon (S4)	75	31.96	4.388	22	42
BEHS (1) Twantay (S5)	75	**29.84**	4.520	20	39
BEHS (2) Twantay (S6)	75	30.72	3.754	24	39
BEHS (1) Mingalardon (S7)	75	33.25	4.756	24	45
BEHS (2) Mingalardon (S8)	75	**35.00**	3.720	28	42
Total / Average	**600**	**32.18**	**4.512**	**23.5**	**41.5**

Based on the results, the mean of Basic Education High School No.(1) Twantay was the lowest and the mean of Basic Education High School No.(2) Mingalardon was the highest. This means that the students from Basic Education High School No.(1) Twantay have the lowest spatial ability and the students from Basic Education High School No.(2) Mingalardon have the highest spatial ability. In addition, Figure 6 illustrated the comparison of the means of students' spatial ability in the selected schools.

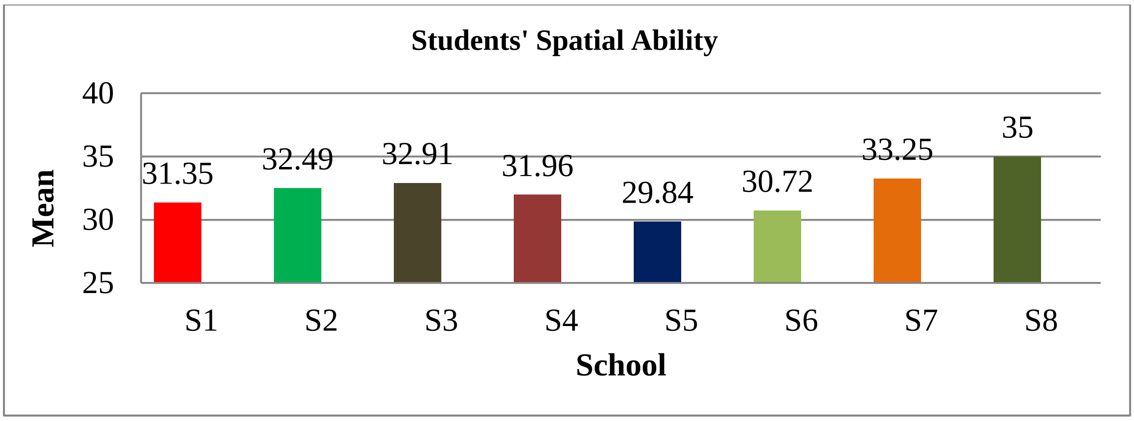

Figure 6 Comparison of Means of Students' Spatial Ability in the Selected Schools

It is necessary to examine the percentage of the students (600) who have low, moderate and high spatial ability. Therefore, a descriptive statistics (percentage) was used. The total score of spatial ability test was (50) marks. The means and standard deviation of all the participants were (32.18) and (4.512) respectively. By using one standard deviation, students who possessed marks above (37) were defined as high achieving in spatial ability. Students who possessed marks between (28) to (37) were defined as moderate achieving in spatial ability and students who possessed marks under (27) were defined as low achieving in spatial ability. Table 8 described the percentage of low, moderate and high levels of students' spatial ability.

Table 8 Students' Spatial Ability Level

Students' Spatial Ability Level	Score	No. of Student	Percentage (%)
Low	0-27	76	12.67
Moderate	28-37	450	75
High	38-50	74	12.33
Total		**600**	**100**

Figure 7 obviously demonstrated the percentage of the students according to their spatial ability level.

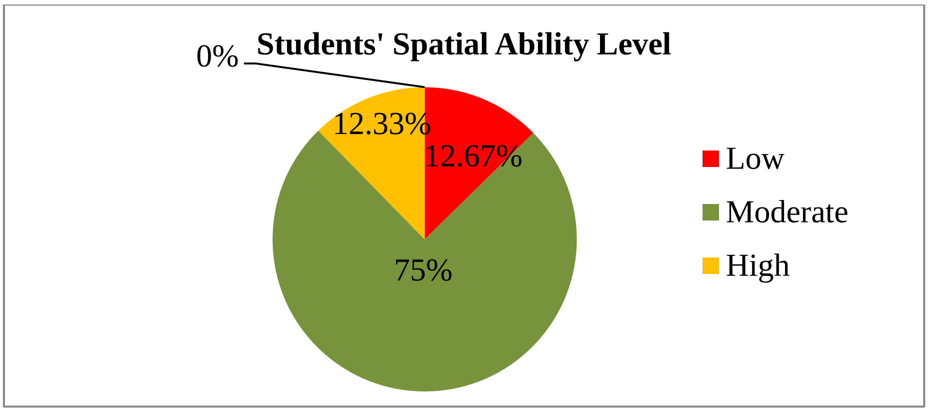

Figure 7 Students' Spatial Ability Level

(7) Findings of Students' Geometrical Performance in the Selected Schools

In order to examine the students' geometrical performance, a test for geometrical performance was administered. It covered three parts: visualization that includes ten multiple choice items, each scoring (1) mark, analysis that includes ten multiple choice items, each scoring (2) mark and informal deduction that includes four problems, each scoring (5) mark. The total score was (50) marks. Table 8 described the comparison of the means of students' geometrical performance in each selected school.

Table 9 Means of Students' Geometrical Performance in the Selected Schools

School	No. of Student	Mean	Standard Deviation	Minimum	Maximum
BEHS (1) Yankin (S1)	75	30.36	3.733	21	39
BEHS (2) Yankin (S2)	75	30.91	3.912	21	43
BEHS (1) Dagon (S3)	75	33.97	5.112	25	47
BEHS (2) Dagon (S4)	75	32.60	3.572	25	45
BEHS (1) Twantay (S5)	75	**29.92**	3.344	20	39
BEHS (2) Twantay (S6)	75	31.47	2.762	27	39
BEHS (1) Mingalardon (S7)	75	32.49	4.134	26	45
BEHS (2) Mingalardon (S8)	75	**36.56**	4.091	28	47
Total / Average	**600**	**32.29**	**4.367**	**24.125**	**43**

According to the results, the lowest mean and the highest mean were (29.92) and (36.56) respectively. Based on the results, students' geometrical performance in Basic Education High School No.(1), Twantay was the lowest and students' geometrical performance in Basic Education High School No.(2) Mingalardon was the highest among the selected schools. Additionally, Figure 8 illustrated the comparison of the means of students' geometrical performance in the selected schools.

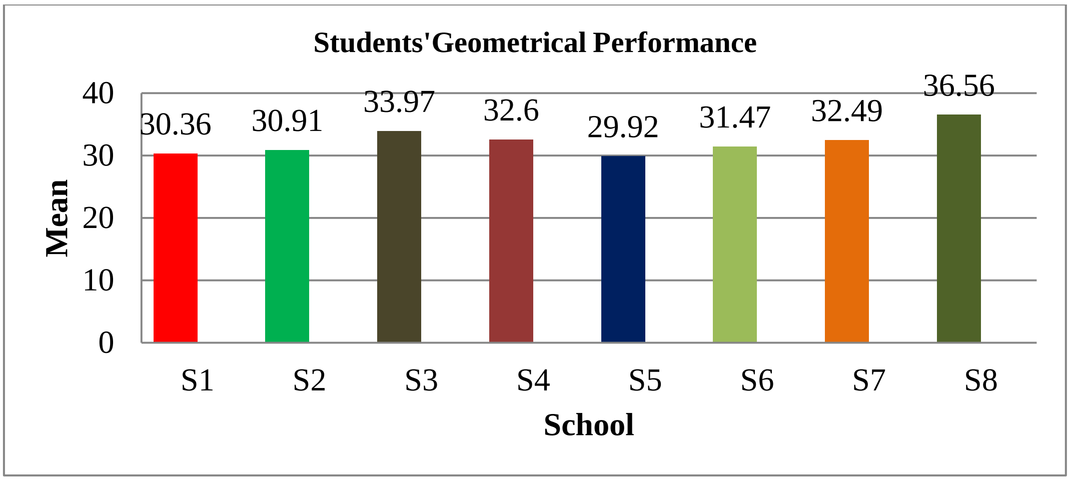

Figure 8 Comparison of Means of Students' Geometrical Performance in the Selected Schools

Moreover, it is necessary to investigate the percentage of the total students (600) who have low, moderate and high geometrical performance. Therefore, a descriptive statistics (percentage) was used. The total score of geometrical performance test was (50) marks. The means and standard deviation of all the participants were (32.29) and (4.367) respectively. By using one standard deviation, students who possessed marks above (39) were defined as high achieving in geometrical performance. Students who possessed marks between (28) to (38) were defined as moderate achieving in geometrical performance and students who possessed marks under (27) were defined as low achieving in geometrical performance. Table 10 described the percentage of low, moderate and high levels of students' geometrical performance.

Table 10 Students' Geometrical Performance Level

Students' Geometrical Performance	Score	No. of Students	Percentage (%)
Low	0-27	42	7
Moderate	28-38	505	84.17
High	39-50	53	8.83
Total		**600**	**100**

Figure 9 obviously illustrated the percentage of the students according to their geometrical performance level in mathematics.

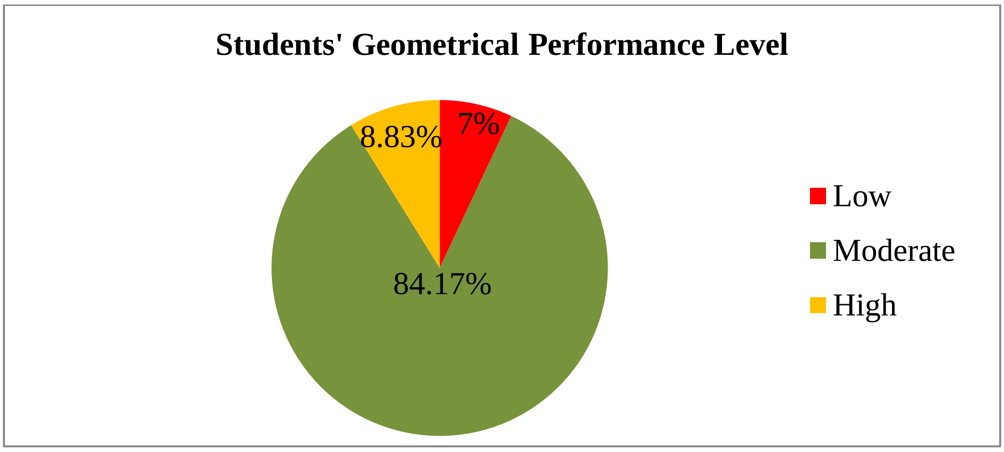

Figure 9 Students' Geometrical Performance Level

(8) Finding the Correlation between Students' Spatial Ability and their Geometrical Performance in Mathematics in the Selected Schools

To investigate the correlation between students' spatial ability and their geometrical performance in mathematics, Pearson product-moment correlation was used. According to Gay & Airasian (2003), correlation coefficient below plus or minus (.35) was interpreted as low or no relation, correlation coefficient between plus or minus (.35) and (.65) was interpreted as moderate relation and correlation coefficient higher than plus or minus (.35) and (.65) was interpreted as high relation.

By using Pearson product-moment correlation, the correlation between students' spatial ability and their geometrical performance was studied. Based on the results, there was a significant correlation ($r(6) = .685$, $p < .01$) between students' spatial ability and their geometrical performance at the 0.01 level. Table 11 described the correlation between students' spatial ability and their geometrical performance in mathematics.

Table 11 Correlation between Students' Spatial Ability and their Geometrical Performance in Mathematics in the Selected Schools

Correlation			
		Students' Spatial Ability	**Students' Geometrical Performance**
Students' Spatial Ability	Pearson Correlation	1	.685**
	Sig. (2-tailed)		.000
	N	600	600
Students' Geometrical Performance	Pearson Correlation	.685**	1
	Sig. (2-tailed)	.000	
	N	600	600

** Correlation is significant at the 0.01 level (2-tailed).

It was found that the direction of correlation was positive and students' spatial ability and their geometrical performance were highly correlated. This means that if the students are good at spatial ability, they will get high marks in geometrical performance.

Discussion, Suggestions and Conclusion

Discussion

Children's early mathematics ability is an important predictive factor to later mathematics achievement. Understanding and promoting children's spatial ability improves children's early mathematics competency. Mulligan (2015) defined spatial ability as the process of recognizing and manipulating spatial properties of objects and the spatial relations among objects. It is very important and necessary to improve students' spatial ability in mathematics classrooms as it helps students develop mathematical thinking and perform better in mathematical activities. So, how to assess spatial ability is an educational priority. With this view, this study seeks to address this demand by investigating the relationship between students' spatial ability and their geometrical performance.

The percentage of low, moderate and high levels of students' spatial ability were 12.67% (N=76), 75% (N=450) and 12.33% (N=74) respectively. So, these findings reveal the answer to the first question: To what extent do students possess spatial ability?

The percentage of low, moderate and high levels of students' geometrical performance were 7% (N=42), 84.17% (N=505) and 8.83% (N=53) respectively. So, these findings reveal the answer to the second question: To what extent do students perform geometrical tasks?

The correlation between students' spatial ability and their geometrical performance was ($r (6) = .685, p < .01$). This result showed that the direction of correlation was positive and a high correlation. It pointed out that if the students' spatial ability was high, their geometrical performance was also high or if the students' spatial ability was low, their geometrical performance was also low. So, this finding revealed the answer to the third question: Is there any significant relationship between students' spatial ability and their geometrical performance in mathematics?

The finding of the correlation between students' spatial ability and their geometrical performance in mathematics supports the finding of Hassan (2002): there was a significant relationship between visual perception of geometric shapes and achievement of secondary school students in geometry. According to Tsutsumi et al., (2005), spatial thinking was also an effective means of enhancing students' mathematical thinking.

Spatial ability is not a unitary construct, but it is a combination of sub-skills such as using maps, solving geometry questions and recognition of two dimensional representations of three-dimensional objects. However, spatial ability is often deprioritized within the classroom because it is rarely assessed. In an age of accountability where students and teachers are being held to higher standards for teaching and learning, educators and policy makers need to take a broad look at the measures and expectations for students' achievement. Grades, standardizes test scores, and cognitive skill assessments such as spatial skill, should all be taken into account when looking at students' learning outcomes.

Additionally, the researcher noticed that students were good at perceptual speed rather than the other spatial performance because they can scan figures and symbols well. They are weak in flexibility of closure because they have few experiences in finding embedded figures. So, the teacher should use instructional strategies to encourage the development of spatial ability. Some specific classroom learning activities should be used to enhance spatial ability such as paper folding, mental rotation tasks, and creating virtual reality environments to make students see virtual buildings from different position and using the tridio learning material. The tridio learning material consists of cubes, with white, black and green sides, mosaic pieces (rhombuses and triangles) in the same color and a board to place the cubes on.

According to the results of the research, a generalization can be drawn that students' spatial ability significantly influenced the students' geometrical performance. Therefore, it can be realized that it is very crucial to enhance students' spatial ability for improving their geometrical performance in mathematics.

Suggestions

Teaching students to become spatial thinkers is increasingly recognized as a goal of education. Spatial ability is found as an important component of success in a variety of scientific, technical and mathematical related occupations. Visual-spatial ability is increasingly important for everyone in rapidly changing technologically oriented world. So, it is necessary to enhance students' spatial ability to face the challenges of 21st century. Teachers' role, students' role and classroom activities for improving spatial ability, assessment for promoting spatial ability and suggestions for further study are given as suggestions.

(i) Teachers' role, students' role and classroom activities for improving spatial ability: Visualization level is where students use imaginary movements in three-dimensional place. In order to develop visualization, the students should understand the arrangements of spatial patterns and several stages to produce the correct solution. And also, the teachers should probe students, act as resource and guide students in direction of outcomes. Moreover, in order to improve students' visualization, the teachers should carry out classroom activities such as paper-based exercises: paper folding, paper form board and surface development tasks.

Spatial relation is where students mentally rotate spatial objects fast and correctly. In order to develop spatial relation, the students should be good at thinking about how an object will look when rotated. This skill can be improved with practice. So, the teachers should integrate some specific activities such as card rotation, flag rotation and cube rotation tasks in mathematics classrooms.

Closure speed is where students quickly identify a familiar meaningful visual object from incomplete visual stimuli without knowing in advance what the object is. To develop this skill, the students must understand gestalt completion and be good at concealed words and figures. This skill can also be improved with practice. So, the teachers should use such learning materials as tangram puzzle and tridio to understand gestalt completion and find concealed words and figures.

Flexibility of closure is where students identify a visual figure or pattern embedded in a complex distracting visual pattern. In order to develop flexibility of closure, the students must be good at noticing embedded figures and hidden patterns. And also, the teachers should provide such learning experiences as finding hidden figures, patterns in teaching-learning process.

Perceptual speed is where students compare figures or symbols or carry out very simple tasks involving visual perception. In order to develop perceptual speed, the students must visualize figures and symbols fast and correctly. And also, the teachers should provide students such learning experiences as comparing figures, scanning symbols and maze tracing in mathematics classrooms.

(ii) Assessment for promoting spatial ability: Multiple-choice items are mostly used in assessment of spatial ability. For this reason, the researcher studied spatial ability using multiple-choice items based on different spatial tasks. Different researchers used spatial ability tests for different purposes. Soma spatial tests are non-verbal tests, perceptual tests for career selection. Teachers should adopt different assessment methods such as paper-based exercises that allow students to visualize spatial patterns fast and correctly. And also, teachers should use games and puzzles that allow students gestalt completion and find hidden figures correctly.

(iii) Suggestions for further study: With this view, some suggestions are provided for further research. In the 21^{st} century, spatial ability is essential in specific areas of engineering, science and mathematics. This research study contributed to the improvement of students' spatial ability in mathematics in the middle schools.

However, no study is perfect in a single effort. In this study, the sample schools were randomly selected from Yangon Region. So, future research should be carried out for the other States and Regions for replication. Moreover, this research is concerned with only the middle school students. That is so, other studies with the primary and the high school students and also the college and the university students should be conducted. In addition, this study was dealt with the students' spatial ability such as visualization, spatial relation, closure speed, flexibility of closure and perceptual speed from Carroll's five major factors of spatial ability. Therefore, future studies should be conducted with other spatial skills. Moreover, future studies should be conducted with other assessments which measure the spatial ability of students.

Conclusion

Education is important because it gives people the baseline skills to survive as adults in the world. These skills include basic literacy and numeracy, problem-solving skill, critical thinking skill and communicating skill. Spatial ability is essential in problem-solving skill and ability to see the relations. People with strong spatial ability can imagine a shape from different view-points or they can quickly understand the spatial patterns. Spatial thinking has a significant role in many school subjects, in everyday life, and in many occupations.

Spatial perception accompanies man from birth. Its development is connected not only with the cognitive processes but also with education. The effective use of spatial information is one aspect of human cognition .Promoting spatial ability in mathematics classes is crucial in the development of successful students. Mathematics teachers should be aware that students must be provided with maximum opportunity of participation to develop their fullest potential.

When students think spatially in mathematics, they easily recognize the relations between geometrical figures, perform better in mathematical activities. Moreover, spatial ability can be improved with practice. Teachers must use classroom activities and games that allow students to improve their spatial ability. Tangram puzzle, a game in which smaller shapes must combine form a larger shape enhances students' spatial thinking.

Finally, the researcher concluded that there was relationship between students' spatial ability and their geometrical performance in mathematics. According to the literature, spatial ability is important not only in daily lives but also in academic life. It can lead to the development of students' ability to recognize the relations, students' performance in geometry and students' problem-solving skill. Additionally, spatial ability supports the students' vocational outcomes. Three major components of spatial ability: space, tools of representation and process of reasoning are helpful for encouraging children in grasping the world and developing mathematical thinking. So, every teacher should create a learning environment in which students think spatially rather than memorizing facts. Although this study cannot fulfill the aim of teaching and learning mathematics in the middle schools, it can be a support for teachers to foster the middle school students' spatial ability in Myanmar.

Acknowledgements

We would like to offer respectful thanks to Dr. Aye Aye Myint, Retired Rector, Yangon University of Education, Dr. Pyone Pyone Aung, Pro-Rector, Yangon University of Education and Dr. Kay Thwe Hlaing, Pro-Rector, Yangon University of Education who give us permission to fulfill our dream of doing this thesis. We wish to express our deepest gratitude to our teacher, Dr Soe Than, Professor and head of Department, Methodology Department, Yangon University of Education for his intellectual resources.

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