The role of gender, age, and ethnicity in spatial test performance of Myanmar middle school students

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1. Introduction

1.1. Importance of the Spatial Ability for Middle School Students

When we need to seek our way around a new school building, we often use the school map. To realize the map, we have to apply spatial ability. For such common activities, spatial ability plays an important role in our daily lives and we use it unconsciously. Lohman (1993) defined spatial ability as an ability to generate, retain, retrieve, and transform well-structured visual images. Spatial ability involves an integrated use of visual spatial capacities to solve problems and expand creative thinking (Gardner, 1983; Hegarty, 2010). Moreover, Gardner (1983) articulated that spatial ability and spatial cognition were the basic building blocks that a child needed in order to develop higher level thinking skills.

Nowadays, spatial ability becomes an important research topic in education (e.g., Kayhan, 2005; Shea, Lubinski, & Benbow, 2001; Tai, Yu, Lai, & Lin, 2003) because there is a strong relationship between spatial ability and an individual achievement; especially, in science (Small & Morton, 1983), physics (Pallrand & Seeber, 1984), chemistry (Baker & Talley, 1972), biology (Lord, 1985), and mathematics (e.g., Maccoby & Jacklin, 1974). Also, Shea et al. (2001) reported that spatial ability can be contributed to the prediction of educational tracks. Some researchers focused the contribution of spatial ability on achievement in elementary and secondary school subjects (e.g., Delialioğlu, 1996; Delialioğlu, & Aşkar, 1999; Kayhan, 2005; Shea et al., 2001; Tracy, 1987).

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Hegarty (2010) and Kayhan (2005) strongly recommended to the teachers, curriculum developers, and researchers to be aware of the importance of spatial ability, to tell the students about the importance of spatial ability, and to prepare concrete activities to develop students' spatial abilities during the elementary and secondary education. Also, Shea et al. (2001) expressed that if the students know their level of spatial ability since their middle school ages, it will help them to improve their spatial skills by practicing and to select major subjects for them at professional colleges and universities. In addition, Barke (1993) found that at the around the age of 14 years (middle school ages), spatial ability is developed to a point that students can interpret the two-dimensional drawings of cubes, tetrahedrons or octahedrons in a spatial way. For these reasons, middle school students were selected as subjects in this study.

1.2. Spatial Ability Tests for Myanmar Middle School Students

Spatial ability tests are getting attention of the psychologists for last couple of decades in Europe and many countries including Japan for educational-vocational purposes (Eliot, 2000; Eliot & Smith, 1983). However, until recent years, Myanmar, one of developing countries, had not yet become widely aware of the importance of spatial ability in education (Khaing, Yamada, & Ishii, 2011, 2012).

In fact, a large number of paper and pencil tests of spatial ability are known to exist. But, when we seek an appropriate spatial ability test to conduct a particular spatial research in Myanmar, there was one thing to consider.

Generally, spatial ability tests are non-verbal tests. But for only this reason, it cannot be said that spatial ability tests are culture-fair tests. Moreover, childhood experiences and cultural factors play a big part in explaining

differences in spatial abilities (e.g., Barke & Engida, 2001). Engida (2000) have studied the students' spatial ability of German schools and Ethiopian schools. Their results tell us that cultural factors have influences on spatial ability, in agreement with the findings of earlier research work by Berry (1971) that used other spatial ability tests. For these reasons, new unique spatial ability tests are necessary to measure the spatial ability of Myanmar students.

Therefore, as a new contribution, Khaing, et al. (2012) developed two equivalent spatial ability tests (S.A.T; form A and form B) for Myanmar middle school students. In order to develop these tests systematically, Khaing et al. (2011, 2012) utilized a two-parameter logistic model (2PLM) of item response theory (IRT). Item response theory (IRT) has now come into widespread application in the fields of educational and psychological measurement because it overcomes an important shortcoming of classical item analysis by providing information on how examinees at different ability levels on the ability have performed on an item (Hambleton, Swaminathan, & Rogers, 1991).

Since spatial ability tests are generally figural tests and participants can memorize the test items during the first test administration, the researchers cannot administer the test to the participants twice for getting test-retest reliability. Therefore, Khaing et al. (2012) developed simultaneously two equivalent tests which were linked by common items, then these were analyzed by using the common item concurrent calibration IRT method, and a test information function was used as a replacement for traditional concepts of reliability and standard error of measurement. As a result, two S.A.T forms could be developed. Since they were developed by the common item IRT equating design, their test scores could be placed on the same scale and their estimated reliabilities were high.

For the test composition, S.A.T forms were designed as multiple-task tests to assess more aspects of spatial ability than single-task tests. Although the S.A.Ts involved four spatial tasks to measure the four different aspects respectively, the main purpose of the tests was to measure the common spatial factor, and thus, the unidimensionality of the test was checked carefully until the test showed a reasonable unidimensionality (Khaing et al., 2012).

Before S.A.T forms were practically utilized in the re-

search of group comparisons concerning spatial ability, the authors had to check significant differences in difficulties of an item between groups who have the same ability. Therefore, as a next step, differential item functioning (DIF) items of the tests were identified and discarded from the tests to ensure that no students will be unfairly panelized when taking the tests. Differential item functioning (DIF) analysis is typically used to identify test items that are differentially difficult for respondents who have the same level of ability but differ in ways that should be irrelevant to their performance on the test (Miller, Chahine, & Childs, 2010).

DIF is said to exist when examinees with the same ability level from different groups have different probabilities of success on a given item. Usually two types of DIF are distinguished: uniform DIF and non-uniform DIF (Mellenbergh, 1982). Uniform DIF occurs when different probabilities of success are found for every ability level; i.e., the test item is easier for one group than for another group at every ability level. In IRT terms this means that the discrimination parameters are same but the difficulty parameters are different. Non-uniform DIF can be occurs when there is an interaction between group membership and ability level. For one end of the ability level spectrum, the item is easier for members of one group, whereas at the other end of the ability level the item is easier for members of the other group. In IRT terms this means that the discrimination parameters and the difficulty parameters are different.

In this study, interest of the research is to look significant differences in item difficulties between different groups who have the same ability, rather than to look individual performance. Thus, item difficulty was considered as the main item characteristic that would influence examinee group performance, and the authors had analyzed S.A.T forms by uniform DIF analysis method. In the DIF analysis, DIF items were identified by using three famous DIF analysis methods; Lord's Chi-square (LC) method, Logistic Regression (LR) method, and Mantel-Haenszel (MH) method, and the common DIF items were discarded from the forms. Since S.A.T forms had been developed as non-DIF tests (Khaing, Yasunaga, & Ishii, 2013), these forms were selected to apply in this research.

1.3. Gender and Age Differences in Spatial Ability

According to the literature, it is acknowledged that males have superior spatial performance than females do (e.g., Eals & Silverman, 1994; Kimura, 1996; Moffat & Hampson, 1996). However, Voyer, Voyer, and Bryden (1995) insisted that there was not a male advantage on all spatial factors.

Linn and Peterson (1985) conducted a meta-analysis for spatial ability research between 1974 and 1982. According to them, different facets/ aspects of spatial ability show different gender effects. Male superiority is the most demonstrative in mental rotation or spatial manipulation (Linn & Peterson, 1985), with lesser differences evident in spatial orientation and no differences evident in spatial visualization (Battista, 1990). Especially, it was found the large performance difference in mental rotation or spatial manipulation. Therefore, Silverman and Eals (1992) and Masters and Sanders (1993) also tested male and female participants on mental rotation tasks, and they found that males were superior in performance, in agreement with previous findings.

However, MacIntyre (1997) did predicting that females are tendency to have superior spatial abilities for specific tasks. According to Sorby (2009), males were more likely to use a "holistic strategy" and females were more likely to use an "analytic strategy." The holistic strategy relies on visualizing the whole object, and the analytic strategy uses a systematic, stepwise approach. Kimura (1996) noted that superior performance by women on a task requiring object location memory has challenged the traditional view that men excel on all spatial tasks. Moreover, according to Voyer et al. (1995), gender difference emergence is highly dependent on the type of spatial tests. These findings highlight that evidence concerns with the differences in specific spatial abilities between males and females is inconsistent.

Therefore, it is imperative to investigate students' spatial abilities by gender in order to confirm the previous researches and to know the levels of spatial ability of Myanmar middle students according to gender.

The next interest is developmental issues of spatial ability. Orde (1996) also found that spatial ability improves with age in childhood years. Barke (1993) found that around the age of 14 years (middle school ages), spatial ability is developed to a point that students interpret the two-dimensional drawings in a spatial way. In addition, Ben-Chaim, Lappan and Houang, (1988) suggest that seventh grade (age of 13–14) is an optimal time for the teaching of spatial visualization tasks. According to Salthouse, Babcock, Skovronek, Mitchell and Palmon (1990), spatial ability seems to reach a plateau at puberty but begins to decline in the late twenties due to the aging effect. Pak (2001) agreed with Salthouse et al. (1990) that the spatial ability declines with age in adulthood.

Furthermore, some studies note that sex differences in spatial ability do exist at pre-pubertal ages (Glasmer & Turner, 1995; Vederhus & Krekling, 1996), specifically at seven or eight years of age. These differences remain constant to age 18 (Johnson & Meade, 1987). Regarding the puberty, many psychologists define that girls begin puberty at ages 10–11; boys at ages 11–12. Girls usually complete puberty by ages 15–17, while boys usually complete puberty by ages 16–17. Then, according to Nyborg (1983), maturation has an effect on spatial development, i.e., late maturation is related to high spatial ability. Therefore, the tendency of both gender and age affecting spatial ability is large, and the fact that how the spatial ability of children change over time on which spatial factors is not clear yet.

As introduced earlier, since the S.A.T forms were constructed by multiple spatial tasks in order to measure more aspects/ factors of spatial ability, by utilizing these tests, age differences in each aspect of spatial ability of the students can be examined more accurately. And, it can be determined whether the results agree with the previous research. Therefore, the next other purpose of this study becomes to investigate students' spatial abilities by age.

1.4. Ethnicity in Spatial Ability

In literature, childhood experiences, environmental differences and cultural factors play a big part in explaining differences in spatial ability (e.g., Barke & Engida, 2001; Berry, 1971; Engida, 2000; Harris, 1978; Khaing et al., 2012; Sherman, 1979). According to the findings of Harris (1978), while evidence for gender or environment (or an interaction of the two) is not conclusive, it is clear that they both play some role in the development of spatial ability. Therefore, the differences that are exhibited among different environmental/ different ethnic groups should also be considered to investigate.

Myanmar has over 100 ethnic groups, who have dif-

ferent cultures, different environments, and different dialects. The largest ethnic minorities are Burma, Shan, Karen, Mon, Rakhine, Chin, Kachin and Kayar. Therefore, one purpose of the study becomes to conduct the research by different ethnic groups who have different cultures. This is to investigate the levels of spatial ability of Myanmar middle school students according to the different ethnic groups.

1.5. Application of IRT Analysis

As explained in the earlier section, two spatial ability test (S.A.T) forms, which would be used in this research, were developed systematically by applying an item response theory (IRT) two-parameter logistic model (Khaing et al., 2011, 2012).

According to DeMars (2010), if different examinees take different tests, the IRT scores can adjust for the difference in difficulty. In fact, IRT is typically applied for defining ability of examinees; estimating scores for examinees on the ability scores; and using the scores to predict or explain item and test performance. IRT scoring puts the scores from the different test forms onto the same metric, so that each examinee can have a customized test form. Moreover, IRT provides an index of the precision of the test score for each examinee. Given a set of test items that have been fitted to an item response models, it is possible to estimate an examinee's ability on the same ability scale from any subset of items (Hambleton & Swaminathan, 1985). Therefore, it was decided to apply an IRT model in this study, too.

1.6. Purpose of the Study

The main purpose of our research is to investigate the role of gender, age, and ethnicity in spatial test performance of middle school students in Myanmar by applying an IRT data analysis. Specifically, the objectives of the study are to:

1 Examine the students' spatial ability by each spatial task.
2 Investigate the level of students' spatial ability by ethnicity, age, and gender.

2. Method

2.1. Participants

For ethnicity analysis, two different ethnic group students in Myanmar were selected. They were sampled from Kachin State and Magway Region. Although their official language is Myanmar language, their typical languages in everyday use are different. Accordingly, their cultures and religions are also different.

Kachin State is one of the seven states of Myanmar. The majority of the population in Kachin State is Kachin. Their language is Kachin and they employ in agriculture. Christianity is the main religion in Kachin State.

Magway Region is the largest of Myanmar's seven regions and over 95% of the people in Magway Region are Burma and use Myanmar language. Most of them are Buddhists. The principal product of Magway Region is petroleum.

2.2. Instrument

The total items of the S.A.T form-A was 32 items, that of the test form-B was 33 items. But, since the two S.A.Ts were developed simultaneously two equivalent tests which were linked by common items, their test scores could be placed on the same scale and their estimated reliabilities were high (Khaing et al., 2012).

Both S.A.Ts were composed of four spatial tasks which measure four aspects of spatial ability. The four spatial tasks were Paper Formboard, Figure Rotation, Paper Folding and Block Rotation. All test items were multiple choice-items with four alternative answers. Table 1 describes sample test items of the four spatial tasks (Khaing, et al., 2012).
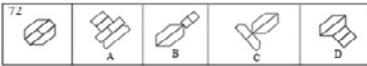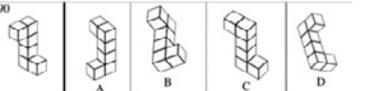
1. Paper Formboard. Each problem has a numbered figure to the left and four lettered figures to the right. Students must find the lettered figure made of exactly the same pieces that are in the numbered figure.

2. Figure Rotation. Students have to indicate which of four figures, when mentally turned or rotated, are different from a given figure

3. Paper Folding. Students must imagine the folding and unfolding of pieces of paper. In each problem, the figures to the left represent a piece of paper being folded. One of the four figures to the right of the vertical line shows where the holes that are in the paper will be when it is completely unfolded. Students have to decide which one of these figures is correct.

4. Block Rotation. Each problem consists of five blocks, and four of them are the same. Students must

Table 1.　Samples of the Four Tasks

Table 2.　Number of students participated in this study

Group Factor	Subgroup	A	B	Total
Ethnicity	Minhla	632	447	1079
	Myitkyinar	219	742	961
Gender	Male	379	589	968
	Female	472	600	1072
Age	13	312	26	338
	14	377	689	1066
	15	162	474	636
Total		851	1189	2040

indicate which block, when mentally turned or rotated, is different from a given block.

Instructions of the test were written in Myanmar Language which is the official language of Myanmar. Each task takes 2 minutes each to complete.

2.3.　Data Collection and scoring

To collect the data for this study, a stratified random sampling technique was used in selecting townships, schools, and subjects. Two townships from the two ethnic populations were randomly selected. They were Myitkyinar Township from Kachin State and Minhla Township from Magway Region. After that, schools and students were randomly sampled.

Two data collections were conducted. The first was performed with the test form-B in the last week of November, 2011. The second was conducted with the test form-A in the last week of December, 2012. Group A (who was analyzed with test form-A) had 851 students and Group B (who was analyzed with test form-B) had 1189 students. Therefore, the total of 2040 students participated.

The number of students participated in this study is shown in Table 2. There were 968 males and 1072 females. Minhla (Burma) group has 1079 students and Myitkyinar (Kachin) group had 961 students. According to the situation of the sample schools, the sample sizes of the two ethnic groups were not the same. Concerning the age, 338 students were 13-years old, 1066 students were 14-years old, and 636 students were 15-years old. After collecting the necessary data, students' responses were

scored. Respondents take 1 if answered correctly and 0 if answered incorrectly.

2.4.　Data Analysis

An item response theory (IRT) parameter estimation procedure was carried out with two-parameter logistic model (2PL), by utilizing Bilog-MG (Zimowski, Muraki, Mislevy, & Bock, 2003), in which "MG" stands for "multiple group".

Two-parameter logistic (2PL) model defines the probability of a positive response to an item i as

$$P_i(\theta) = \frac{e^{Da_i(\theta - b_i)}}{1 + e^{Da_i(\theta - b_i)}} \qquad i = 1, 2, ..., n \qquad (1)$$

where $P_i(\theta)$ is the probability that a randomly chosen examinee with ability θ answers item i correctly, values of $P_i(\theta)$ are between 0 and 1 over the ability scale. b_i is the item i difficulty parameter, a_i is the item discrimination (or slope) parameter, n is the number of items in the test, e is a transcendental number whose value is 2.718, and D is a scaling factor (Hambleton et al., 1991), which is set as 1 in this study.

To explore whether there were any significant differences of student spatial ability among different groups, analysis of variance (ANOVA) and independent sample t-test were also conducted.

3.　Results

3.1.　Examining the Spatial Abilities of Students from Both Group A and Group B

Firstly, an IRT parameter estimation procedure was
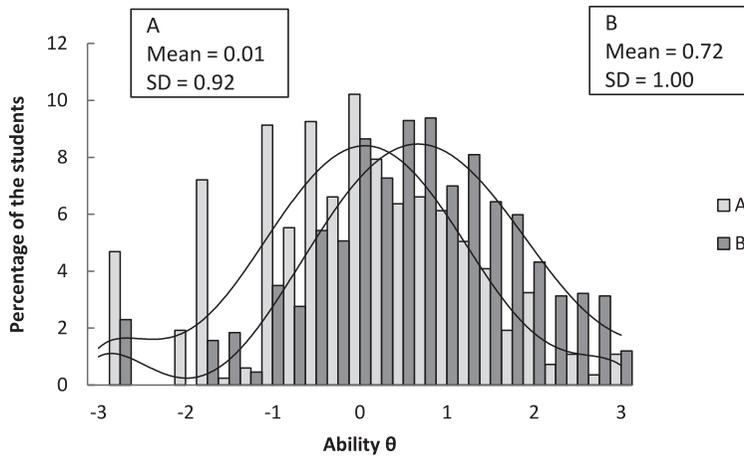
Note: The area under the bell-shaped curves of examinee frequency equal the total areas of the histogram.

Figure 1. Frequency Distribution of Ability Scores of the Students

carried out with a two-parameter logistic (2PL) IRT model for both of Group A and Group B simultaneously. In the estimation phase, the ability parameter (θ) distribution of the examinees was assumed as a standard normal distribution (mean=0, SD=1). Since item parameter estimates were calibrated by common item concurrent calibration IRT method, items of the two test forms could be adjusted on the same ability scale and the result can be analyzed on the same ability scale.

Figure 1 illustrates the frequency distribution of ability scores of the students of Group A and Group B. According to the result of the ability parameter estimation, it can be observed that group mean and standard deviation of the students' spatial ability ($\hat{\theta}$) for the Group A (N=851) are 0.01 and 0.92, and those for Group B (N=1189) are 0.72 and 1.00, respectively. Therefore, it can be concluded Group B students had more spatial ability than Group A students.

3.2. Examining the Spatial Abilities of Students for Each Task

Next, spatial abilities of the students for Each Task were examined. Table 3 and Figure 2 illustrate the ability values ($\hat{\theta}$) of students in each task.

The mean ability values ($\hat{\theta}$) of four tasks were 0.68 in spatial perception factor, 0.27 in spatial orientation factor, 0.42 in spatial visualization factor, and 0.29 in spatial manipulation factor. Among them, the mean ability value of the task of spatial perception factor was the highest.

Table 3. Ability Values ($\hat{\theta}$) of Spatial Ability in Four Tasks

Spatial factors	Tasks	Mean	SD
Spatial Perception	1. Paper Formboard	0.68	1.51
Spatial Orientation	2. Figure Rotation	0.27	1.10
Spatial Visualization	3. Paper Folding	0.42	1.43
Spatial Manipulation	4. Block Rotation	0.29	1.20
Total		0.49	1.39

Therefore, it was concluded that the students were able to solve spatial perception items more than other task items. In addition, since the ability values (θ) for each task were above $\theta = 0$ (+0.27 ~ +0.68), and the ability scores for the whole test was $\theta = 0.49$, it was interpreted that the students had moderate level of the spatial ability in all tasks, and in the whole test.

3.3. Examining the Levels of Students' Spatial Ability by Ethnic Groups

As a next step, ethnic group analysis was executed. So as to observe clearly the significant difference of students' spatial ability between the two ethnic groups, an independent t-test was executed.

The result revealed differences in means and standard deviations of ability scores of four tasks of the test with respect to the groups (See Table 4 and Figure 3). Ability
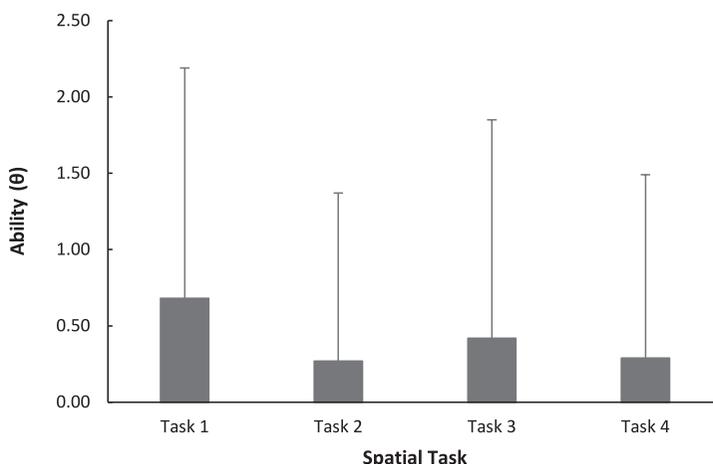
Note: Error bar shows Standard Deviation

Figure 2.　Comparison of Spatial Abilities of Students in the Four Tasks

Table 4.　Result of t-test by Ethnicity for each Spatial Tasks

Tasks	Ethnic	N	Mean	SD	t	df	p	Mean Difference
1. Paper formboard	Minhla	1079	0.27	1.45	−13.678	2038	0.000***	−0.88
	Myitkyinar	961	1.14	1.44				
2. Figure rotation	Minhla	1079	−0.15	0.97	−19.81	2038	0.000***	−0.89
	Myitkyinar	961	0.73	1.05				
3. Paper folding	Minhla	1079	−0.12	1.29	−19.79	2038	0.000***	−1.15
	Myitkyinar	961	1.03	1.34				
4. Block rotation	Minhla	1079	−0.21	1.00	−21.77	2038	0.000***	−1.05
	Myitkyinar	961	0.84	1.18				
Total	Minhla	1079	−0.16	1.03	−25.748	2038	0.000***	−1.38
	Myitkyinar	961	1.22	1.38				

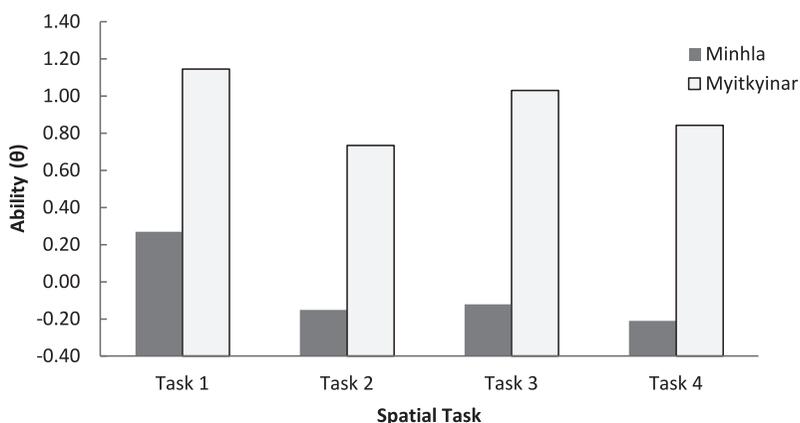Note: *p< 0.05 level, **p< 0.01 level, ***p< 0.001 level

Figure 3.　Comparison of Spatial Ability Scores of ethnic groups

mean scores of four tasks of the test were 0.27, –0.15, –0.12, –0.21 in Minhla group, and 1.14, 0.73, 1.03, and 0.84 in Myitkyinar group. The result showed that the levels of spatial ability of Myitkyinar students were apparently higher than those of Minhla students. According to the t-test result, there were significant differences between the two groups for all tasks of the test at α = 0.001 level (Table 4).

3.4. Examining the Levels of Students' Spatial Ability by Gender

Regarding with the gender effect, gender differences in spatial ability were examined by using independent sample t-test. Table 5 presents result data on gender differences including a measure of mean difference between males and females.

It can be seen that spatial ability of male students (mean θ score = 0.55) was higher than that of female students (mean θ score = 0.43.), and it was significant at α = 0.05 (see Table 5). Concerning the specific spatial factors, males performed better than females in spatial perception, spatial orientation, and spatial manipulation but for spatial visualization they were nearly the same (0.41 and 0.43). The differences between males and females were significant in tasks of spatial perception (p< 0.001 level), spatial orientation (p< 0.01 level), and spatial manipulation (p< 0.01 level), but there was no significant difference in the task of spatial visualization. Therefore, it was concluded that males outperformed females in some not all of spatial tasks. This result can be clearly seen in Figure 4, too.
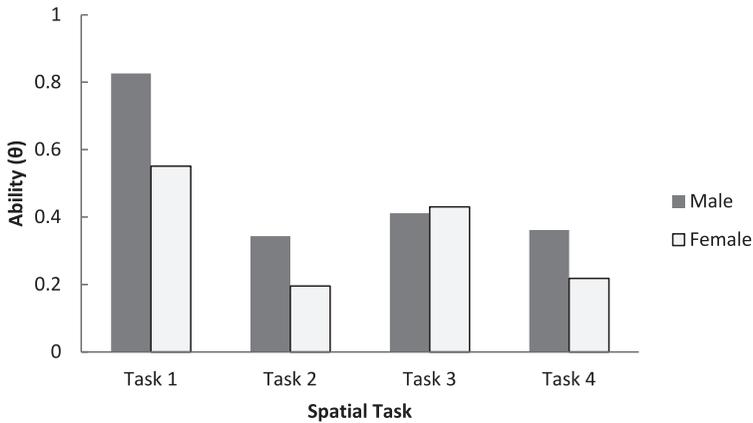

Figure 4.　Mean Comparison of Spatial Ability Scores by Gender

Table 5.　Result of t-test by Gender for each Spatial Tasks

Tasks	Gender	N	Mean	SD	t	df	p	Mean Difference
1. Paper formboard	Male	968	0.83	1.56	4.119	2038	0.000***	0.27
	Female	1072	0.55	1.45				
2. Figure rotation	Male	968	0.34	1.13	3.027	2038	0.003**	0.15
	Female	1072	0.20	1.07				
3. Paper folding	Male	968	0.41	1.32	–0.291	2038	0.771	–0.02
	Female	1072	0.43	1.53				
4. Block rotation	Male	968	0.36	1.25	2.687	2038	0.007**	0.14
	Female	1072	0.22	1.16				
Total	Male	968	0.55	1.35	2.020	2038	0.043*	0.12
	Female	1072	0.43	1.42				

Note: *p< 0.05 level, **p< 0.01 level, ***p< 0.001 level

3.5. Examining the Levels of Students' Spatial Ability by Age

The next step was to examine the age effect. To compare the ability scores of the three age groups, one way ANOVA was utilized. The ANOVA result showed that spatial ability scores differed significantly among the three age groups ($F(2, 2034) = 29.89$, $p < 0.001$).

Table 6 describes the means and standard deviations of the ability scores of three age groups across the four tasks.

Looking at Table 6, it can be seen that the mean ability scores in each task for three age groups are increasing from age of 13 to 15 (i.e., –0.05, 0.54, and 0.68). The mean of ability scores of 13-year students was the smallest and that of 15-year students was the greatest. To obtain more detailed information, Post Hoc Test was executed by Tukey's HSD method. The result showed that ability mean scores of the 14-year group were greater than the 13-year group in all spatial tasks ($p< 0.001$). Also, the ability scores of the 15-year group were greater than the 14-year group in tasks of spatial perception, spatial orientation, and spatial visualization. But for spatial manipulation, it

Table 6.　Mean and Standard Deviation of Students' Age Groups

Spatial factor	Task	Age group			Total (N= 2040)
		13 (N=338)	14 (N=1066)	15 (N=636)	
Spatial Perception	1. Paper formboard	–0.06 *1.44*	0.77 *1.47*	0.92 *1.48*	0.68 *1.51*
Spatial Orientation	2. Figure rotation	0.07 *0.01*	0.27 *1.11*	0.35 *1.12*	0.27 *1.10*
Spatial Visualization	3. Paper folding	–0.17 *1.27*	0.47 *1.43*	0.64 *1.44*	0.42 *1.43*
Spatial Manipulation	4. Block rotation	0.00 *1.03*	0.35 *1.23*	0.32 *1.24*	0.29 *1.21*
Total		–0.05 *1.06*	0.54 *1.40*	0.68 *1.44*	0.49 *1.39*

Note: The upper is mean, and the lower (Italic) is standard deviation (*SD*).
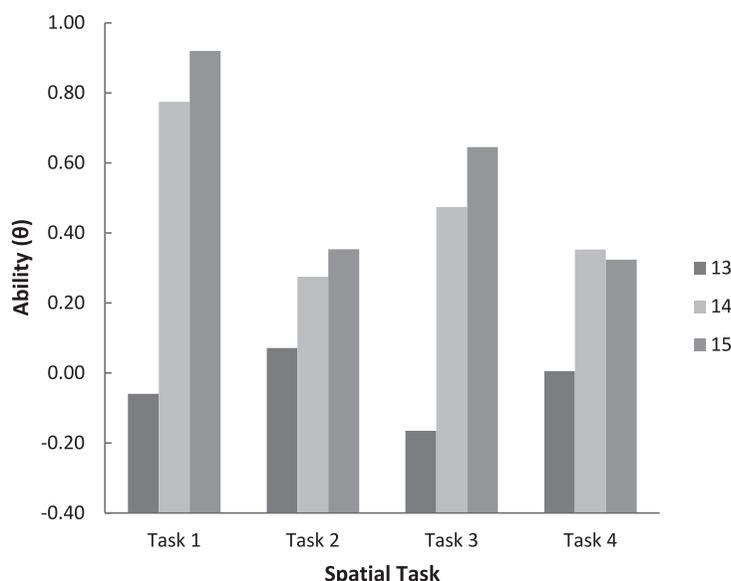

Figure 5.　Mean Comparison of Spatial Ability Scores by Age

was found that the mean score of the 14-year group was a little higher than the 15-year group although there was no significant difference between them (p=0.985).

3.6. Examining the Age-Gender Interaction effect on Levels of Students' Spatial Ability

As a next step, it was investigated whether spatial ability can be affected by age level across gender, the result showed an interaction effect of age and gender. It was noted that both males and females were tendency to develop from age of 13 to 15. Specifically, spatial ability of females was likely to develop from age of 13 to 15 but that of males' spatial ability was likely to remain the same at the age of 14 and 15 (See Table 7 and Figure 6). According to ANOVA result, the interaction effect of age and gender was significant, F (2, 2034) = 3.256, at α = 0.05 level.

3.7. Analyzing Students' Spatial Ability by Gender, Age, and Ethnic Groups

Finally, the overall comparison for the students' spatial abilities was performed by gender, age, and ethnic groups. Table 8 and Figure 7 clearly illustrates the comparison of findings of this research.

Table 8 and Figure 7 illustrate the mean comparisons of spatial ability of three group factors. Concerning the ethnic group comparison, there were apparently differences of spatial ability between the two ethnic groups, and the Myitkyinar had the higher spatial ability than Minhla. Then, it was found that spatial abilities of students were different between males and females. Males had superior spatial performance than females did in some but not all spatial tasks. Concerning the age factor, the ability values of three age groups were distinctly different and improved from the younger group to the elder group. According to the interaction effect of age and gender, males were likely to develop their spatial ability obviously from age of 13 to 14 but not from the age of 14 to 15. Females were tendency to develop their spatial ability from the age of 13 to 15.

4. Discussion and Further Research

4.1. Concerning the Levels of Spatial Ability of Students in Each Task

As expressed earlier, students' spatial ability was identified in this research by Task-1: Paper Formboard (spatial perception items), Task-2: Figure Rotation (spatial orientation items), Task-3: Paper Folding (spatial visualization items) and Task-4: Block Rotation (spatial manipulation items), respectively.

Our results reported that students of this study performed the best in items of Task-1 among four tasks of the spatial test. Therefore, it was concluded that the students had the highest spatial perception ability among all factors. In other words, Myanmar middle school students

Table 7. Means and Standard Deviation of the Spatial Ability of Three Age Groups across Gender

Gender	Age group			Total (N= 2040)
	13 (N=338)	14 (N=1066)	15 (N=636)	
Male	0.15 *1.1*	0.62 *1.36*	0.62 *1.4*	0.55 *1.35*
Female	−0.18 *1.02*	0.48 *1.44*	0.75 *1.49*	0.43 *1.42*
Total	−0.05 *1.06*	0.54 *1.4*	0.68 *1.44*	0.49 *1.39*
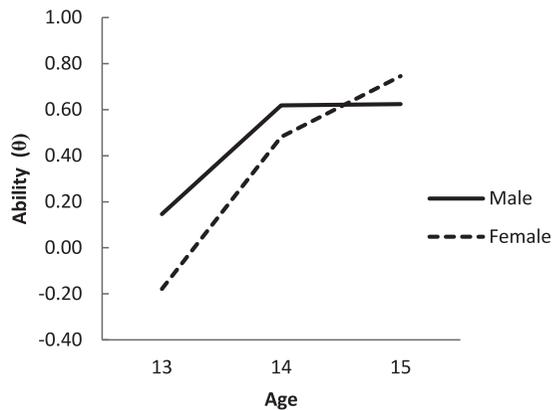
Figure 6. Mean Differences of Spatial Ability of Three Age Groups across Gender

Table 8. Mean Comparisons between the Levels of Students' Spatial Ability

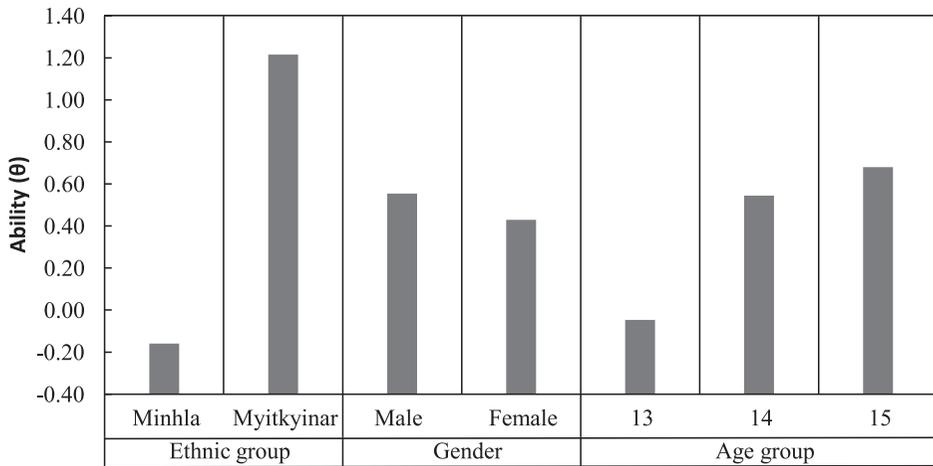| Group Factor	Subgroup	Mean	*SD*
Ethnic group	Minhla	−0.16	1.03
	Myitkyinar	1.22	1.38
Gender	Male	0.55	1.35
	Female	0.43	1.42
Age group	13	−0.05	1.06
	14	0.54	1.40
	15	0.68	1.44

Figure 7. Mean Comparisons of Spatial Ability Scores

of this study had high ability to recognize relationship between objects.

4.2. Concerning the Level of Students' Spatial Ability by Ethnic Groups

According to the previous research (Bowles, 1998; Boyd & Richerson, 1985), education, experience and environmental factors have been shown to improve spatial ability. In this research, an ethnic group analysis was executed. The result revealed that spatial abilities of Myitkyinar students were significantly higher than those of Minhla students. In fact, Myitkyinar students were Kachins from Myitkyinar which is the capital city of Kachin State in Myanmar. Moreover, the participated schools of Myitkyinar were big and famous for their matriculation exam results in Kachin State. So, Myitkyinar students may have better socioeconomic status and education of parents than Minhla students. Therefore, it may be one reason why they had significantly higher spatial ability than those of the other groups.

Another reason may be that their cultural or ethnical differences affected the spatial ability. In this study, Myitkyinar students were from Kachin State in Myanmar whereas Minhla students were Burmar from Magway Region. Myitkyinar students and Minhla students were different in not only ethnicity but also their daily lives. Typically, Kachin students are more likely to participate in activities such as playing sports, singing traditional songs, and dancing together with peer group whenever they have a free time. Contrast to Myitkyinar students,

most of Minhla students said their hobbies were reading books, and some said they liked to play computer games.

In literature, some researchers believe that musical background (Heitland, 2000; Robichaux, 2002) are potential roots for the development of spatial ability. Baenninger and Newcombe's (1989) meta-analysis found spatial activity participation was more probably to be related to spatial ability for both genders. Activities that have been found to improve spatial ability include creating artwork (Caldera, Culp, O'Brian, Truglio, Alvarez & Huston, 1999), previous geometry instruction, experience, and participation in a certain sports (Sorby, Leopold & Gorska, 1999). Therefore, all of these finding support the fact that why spatial abilities of Myitkyinar students were significantly higher than Minhla students.

4.3. Concerning the Level of Students' Spatial Ability by Gender

In literature, there was a general agreement among many researchers, and it was that spatial ability of males is higher than that of females in literature (e.g., Caplan, MacPherson, & Tobin,1985; Kali & Orion, 1996). Our finding showed that males performed better in spatial tasks than females, in agreement with previous findings (e.g., Linn & Peterson, 1985; Masters & Sanders, 1993; Silverman & Eals, 1992). When it was studied their differences in the four spatial factors, it was found no evident for gender differences in spatial visualization but significant differences in the other spatial factors, with the agreement with result of Linn and Peterson (1985) and Battista

(1990). As MacIntyre (1997) reported, females may be tendency to have superior spatial abilities for specific tasks, but it was not found any evidence in our research. However, it should be accepted that gender difference emergence is highly dependent on the type of the spatial test. Nevertheless, as evidence is still inconsistent regarding the differences in specific spatial abilities between males and females, further studies are necessary to conduct.

4.4. Concerning the Level of Students' Spatial Ability by Age

Related to the age effect, it was observed that the means of ability scores in each task for three age groups were different. Thus, it was concluded that their spatial ability has age affect. Then, it was found that spatial abilities were likely to develop from the level of the younger student group to that of the elder student group, especially females obviously develop from 13 to 15, males from 13 to 14.

Here, we consider two reasons for that. One reason is concerning academic course learning in their grades. As presented in the section 1, many researchers mentioned that there is a strong relationship between spatial ability and an achievement in academic area. In our case, 15-year students were learning Grade-9 courses which compose of more lessons which are considered stimuli behind strong development of spatial skills than 14-year students who were learning the Grade-8 courses and 13-year students who were learning Grade-7 courses. Following with the finding of Johnson and Meade (1987), this finding suggested that their spatial ability levels can depend on course of academic subjects which they are learning in the schools.

Another reason is students' cognitive development. It is well documented that spatial ability develops childhood to adulthood. Orde (1996) viewed that spatial ability improves with age in childhood years. McGee (1979) and Weber (1976) stated that pubertal change can explain development of spatial ability in early adolescence. Salthouse et al. (1990) agreed that spatial ability improves a plateau at puberty. According to Newcombe and Bandura (1983), masculinity of males and maturation rate of females had independent associations with spatial ability. In our research, it was observed that spatial ability was tendency to develop from age of 13 to 15 of

females. However, for males, significant difference was found between age of 13 and 14 but not between age of 14 and 15. This result suggested that both pubertal change and age factor could be sources of sex differences in spatial ability. As another finding, Salthouse et al. (1990) stated that this development would begin to decline in the late twenties due to the aging effect. Following the finding of Ben-Chaim et al. (1988), the result suggested that seventh grade (age of 13–14) is an optimal time for the teaching of spatial visualization tasks. Therefore, it is necessary to conduct this study as not only a cross-sectional research but also a longitudinal research with these students to investigate their spatial development.

4.5. Further Research

One limitation of this study was sampling data for ethnic groups. Myanmar has seven states and seven regions. The samples of the current study were selected only from Kachin State and Magwe Region of Myanmar. Therefore, it is necessary to conduct this study as not only a cross-sectional research but also a longitudinal research with these students to investigate their spatial development. Moreover, following with the finding of Johnson and Meade (1987), this finding suggested that their spatial ability levels can depend on course of academic subjects which they are learning in the schools. Therefore, further researches are necessary for the relation between spatial ability and course of academic subjects by using other student groups from other states and regions. In addition, there were different effects on gender, age, gender across age, and distinctly different effects on ethnicity factor. Therefore, to confirm the results, we are necessary to focus on a longitudinal research in future. Moreover, the current study performed analyses for differences in spatial ability across only age, gender and ethnicity factors. Thus, a further research is also necessary to examine the other potential differences (e.g., respondent's test experience, and participation in a certain sports, creating artwork).

5. Conclusion

In conclusion, the levels of spatial ability of Myanmar middle school students were investigated across age, gender and ethnicity in this paper. The results of the study highlighted the facts that 1) age, gender, and

ethnicity affect distinctly each factor of spatial ability development, and 2) interaction of age and gender makes the students to be superior spatial abilities. However, only this evidence is still inconsistent regarding the role of gender, age, and ethnicity in spatial test performance of Myanmar Middle School Students, further studies are necessary to investigate longitudinal data with these students. Nevertheless, the results of this study provide some information in order to know about spatial ability related to gender, age and ethnic factors.

References

Baenninger, M., & Newcombe, N. (1989). The role of experience in spatial test performance: A meta-analysis. *Sex Roles*, **20**, 327-344.

Baker, S., & Talley, L. (1972). The relationship of visualization skills to achievement in freshman chemistry. *Journal of Chemical Education*, **49**, 775-777.

Barke, H.-D. (1993). Chemical education and spatial ability. *Journal of Chemical Education*, **70**, 968-971.

Barke, H,-D., & Engida, T. (2001). Structural chemistry and spatial ability in different cultures. *Chemistry Education: Research and Practice in Europe*, **2**, 227-239.

Battista, M. T. (1990). Spatial visualization and gender differences in high school geometry. *Journal for Research in Mathematics Education*, **21**, 47-60.

Ben-Chaim, D., Lappan, G., & Houang, R. T. (1988). The effect of instruction on spatial visualization skills of middle school boys and girls. *American Educational Research Journal*, **25**, 51-71.

Berry, J. W. (1971). Ecological and cultural factors in spatial perceptual development. *Canadian Journal of Behavioral Science*, **3**, 324-329.

Bowles, S. (1998). *Cultural group selection and human social structure: The effects of segmentation, egalitarianism, and conformism*. Unpublished manuscript, University of Massachusetts at Amherst.

Boyd, R., & Richerson, P. (1985). *Culture and the evolutionary process*. Chicago: University of Chicago Press.

Caldera, Y. M., Culp, A. M., O'Brian, M., Truglio, R. T., Alvarez, M., & Huston, A. C. (1999). Children's play preferences, construction play with blocks, and visual-spatial skills: Are they related? *International Journal of Behavioral Development*, **23**, 855-872.

Caplan, P. J., MacPherson, G. M., & Tobin, P. (1985). Do sex-related differences in spatial abilities exist? A multilevel critique with new data. *American Psychologist*, **40**, 786-799.

Delialioğlu, Ö. (1996). *Contribution of students' logical thinking ability, mathematical skills and spatial ability on achievement in secondary school physics*. Dissertation, Ankara: Middle East Technical University.

Delialioğlu, Ö. & Aşkar, P. (1999). Contribution of Students' Mathematical Skills and Spatial Ability in Secondary School Physics, *Journal of Hacettepe Faculty of Education*, **16-17**, 34-39.

DeMars, C. (2010). *Item Response Theory*. Oxford University Press.

Eals, M., & Silverman, I. (1994). The hunter-gatherer theory of spatial sex differences: Proximate factors mediating the female advantage in recall of object arrays. *Ethology and Sociobiology*, **15**, 95-105.

Eliot, J. C. (2000). The nature and measurement of spatial intelligence, *Institute for child Study*, College of Education, The University of Maryland.

Eliot, J. C., & Smith, I. M. (1983). *An international directory of spatial tests*. Windsor, England: NFER-Nelson.

Engida, T. (2000). *Structural chemistry and spatial ability in chemical education*. A case of selected German and Ethiopian schools (Dissertation). Muenster, Germany: University of Muenster.

Gardner, H. (1983). *Frames of mind*. New York: Basic Book Inc.

Glasmer, F. D., & Turner, R. W. (1995). Youth sport participation and associated sex differences on a measure of spatial ability. *Perceptual and Motor Skills*, **81**, 1099-1105.

Hambleton, R. K., & Swaminathan, H. (1985). *Item Response Theory: Principles and Applications*, Boston, Kluwer.

Hambleton, R. K., Swaminathan, H., & Rogers, H. J. (1991). *Fundamentals of item response theory*. Newbury Park, CA: Sage Publications, Inc.

Harris, L. J. (1978). Sex differences in spatial ability: Possible environmental, genetic, and neurological factors. In M. Kinsbourne (Ed.), *Asymmetrical function of the brain*. London: Cambridge University, pp. 405-521.

Hegarty, M. (2010). Components of spatial intelligence. *Psychology of Learning and Motivation*, 52, 265-297.

Heitland, L. (2000). Learning to make music enhances spatial reasoning. *Journal of Aesthetic Education*, 34, 179-237.

Johnson, E. S., & Meade, A. C. (1987). Developmental patterns of spatial ability: an early sex difference. *Child Development*, 58, 725-740.

Kali, Y., & Orion, N. (1996). Spatial abilities of high-school students in the perception of geologic structures. *Journal of Research in Science Teaching*, 33, 369-391.

Kayhan, E. B. (2005). *Investigation of high school students' spatial ability*. Master Thesis, Middle East Technical University, Turkey.

Khaing, N. N., Yamada, T., & Ishii, H. (2011). A study on developing a spatial ability test for Myanmar middle school students. *Bulletin of the Graduate School of Education and Human Development*, Nagoya University Press, 58, 1-12.

Khaing, N. N., Yamada, T., & Ishii, H. (2012). Developing two equivalent spatial ability tests for Myanmar middle school students. *Japanese Journal for Research on Testing*, 8, 49-67.

Khaing, N. N., Yasunaga, K., & Ishii, H. (2013). Differential item functional analysis of the spatial ability test for Myanmar middle school students: Gender and ethnicity based comparison, *Japanese Journal for Research on Testing*, 9, 85-106.

Kimura, D. (1996). Sex, sexual orientation and sex hormones influence human cognitive function, *Current Opinion in Neurobiology*, 6, 259-263

Linn, M. C., & Peterson, A. C. (1985). Emergence and characterization of gender differences in spatial abilities: A meta-analysis. *Child Development*, 56, 1479-1498.

Lohman, D. F. (1993). Spatial Ability and G. Paper presented at the first Spearman Seminar, University of Plymouth.

Lord, T. R. (1985). Enhancing the visuo-spatial aptitude of students. *Journal of Research in science Teaching*, 22, 395–405.

MacIntyre, T. (1997). Gender differences in cognition: A minefield of research issues. *The Irish Journal of Psychology*, 18, 386-396.

Maccoby, E. E., & Jacklin, C. N. (1974). *The Psychology of Sex Differences*. Stanford, CA: Stanford University Press.

Masters, M. S., & Sanders, B. (1993). Is the gender difference in mental rotation disappearing? *Behavior Genetics*, 23, 337-341.

McGee, M. G. (1979). Human spatial abilities: Psychometric studies, and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*, 86, 889-918.

Mellenbergh, G. J. (1982). Contingency table models for assessing item bias. *Journal of Educational Statistics*, 7, 105-118.

Miller, T., Chahine, Ss., & Childs, R. A. (2010). Detecting differential item functioning and differential step functioning due to differences that should matter. *Practical Assessment, Research & Evaluation*, 15, 1-13.

Moffat, S. D., & Hampson, E. (1996). A curvilinear relationship between testosterone and spatial cognition in humans: possible influences of hand preference. *Psychoneuroendocrinology*, 21, 323-337.

Newcombe, N. & Bandura, M. M. (1983). Effect of age at puberty on spatial ability in girls: A question of mechanism. *Developmental Psychology*, 19, 215-224.

Nyborg, H. (1983). Spatial ability in men and women: review and new theory. *Advances in Behaviour Research and Therapy*, 5, 89-140.

Orde, B. J. (1996). A correlational analysis of drawing ability and spatial ability. *Dissertation Abstracts International*, 57, 1943.

Pallrand, G. J., & Seeber, F. (1984). Spatial ability and achievement in introductory physics. *Journal of Research in Science Teaching*, 21, 507–516.

Pak, R. (2001). A further examination of the influence of spatial abilities on computer task performance in younger and older adults. Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting, Minneapolis, MN, pp. 1551-1555.

Robichaux, R. (2002). Predictors of spatial visualization: Structural equations modeling test of background variables. *Journal of Integrative Psychology*, 2, 15-23.

Salthouse, T. A., Babcock, R. L., Skovronek, E., Mitchell, D. R. D., & Palmon, R. (1990). Age and experience effects in spatial visualization. *Developmental Psy-*

chology, **26**, 128-136.

Shea, D. L, Lubinski, D., & Benbow, C. P. (2001). Importance of assessing spatial ability in intellectually talented young adolescents: A 20-year longitudinal study. *Journal of Educational Psychology*, **4**, 207-230.

Sherman, J. (1979). Predicting mathematics performance in high school girls and boys. *Journal of Educational Psychology*, **71**, 242-249.

Silverman, I., & Eals, M. (1992). Sex differences in spatial abilities: Evolutionary theory and data. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 531-549). New York: Oxford Press.

Small, M. Y., & Morton, M. E. (1983). Spatial visualization training improves performance in organic chemistry. *Journal of College Science Teaching*, **13**, 41-43.

Sorby, S. A., Leopold, C., & Gorska, R. (1999). Cross-cultural comparisons of gender differences in the spatial skills of engineering students. *Journal of Women and Minorities in Science and Engineering*, **5**, 279-291.

Sorby, S. (2009). Educational research in developing 3-D spatial skills for engineering students, *International*

Journal of Science Education, **31**, 459-480.

Tai, D. W. S., Yu, C. H., Lai, L. C., & Lin, S. J. (2003). A study on the effects of spatial ability in promoting the logical thinking abilities of students with regard to programming language. *World Transactions on Engineering and Technology Education*, UICEE, **2**, 251-254.

Tracy, D. M. (1987). Toys, spatial ability, and science and mathematics achievement: Are they related? *Sex Roles*, **17**, 115-138.

Vederhus, L., & Krekling, S. (1996). Sex differences in visual spatial ability in 9-year-old children. *Intelligence*, **23**, 33-43.

Voyer, D., Voyer, S., & Bryden, P. (1995). Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. *Psychological Bulletin*, **117**, 250-270.

Weber, D. P. (1976). Sex differences in cognition: a function of maturation rate? *Science*, **192**, 572-574.

Zimowski, M., Muraki, E., Mislevy, R. J., & Bock, R. D. (2003). *BILOG-MG 3: Item analysis and test scoring with binary logistic models*. Chicago, IL: Scientific Software. [Computer software]

ABSTRACT

The role of gender, age, and ethnicity in spatial test performance of Myanmar middle school students

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This study was conducted to investigate the role of gender, age, and ethnicity in spatial test performance of Myanmar middle school students by using two equivalent spatial ability tests (S.A.T; form A and form B). It considered examining four spatial factors such as spatial perception, spatial orientation, spatial visualization and spatial manipulation. Therefore, the tests include four tasks; Paper Formboard for spatial perception, Figure Rotation for spatial orientation, Paper Folding for spatial visualization and Block Rotation for spatial manipulation. Two thousands and forty students from two different ethnic groups participated in this study. Age range of all participants was 13 to 15 years. Results indicated that spatial perception ability was the best among four factors of spatial ability. Then, Male superior was occurred in three but not all spatial tasks. Elder students did better in the spatial ability items than younger students did. Besides, it was noted there was an interaction of age and gender that makes the students to be superior spatial abilities. Especially, females were tendency to develop their spatial ability from the age of 13 to 15. For males, there was no significant ability difference between 14-year group and 15-year group. In addition, students' spatial ability levels were different due to the different ethnicity.

Key words: spatial ability, gender difference, age difference, ethnicity