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Dynamic Geometry Environment to Enhance High School Students Spatial Skill: A Study Based on Sex and Gender Diversities Perspective

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Abstract
This research is an experimental quantitative approach that aims to determine the impact of sex and gender differences on senior high school students' spatial ability through the implementation of dynamic geometry environment (DGE). Ninety-six high-school student participants were categorized based on gender and sex diversities. Data were analyzed using a three-way ANOVA statistical test and Tukey Test. This study indicates that sex and gender differences and the interaction between sex and gender differences significantly affect students' spatial abilities. The male students outperform the females. The undifferentiated students outperform all students with different genders (feminine, masculine, and androgyny).

Key words: *teaching geometry, sex, gender, spatial ability*

Introduction

Geometry is an essential part of mathematics that gives students a deep appreciation of the world around them. To understand geometry properly, students need spatial ability (Furner & Marinas, 2007). High school students need spatial skills to study advanced geometry, but most of them failed to solve geometric problems from previous studies because they did not have adequate spatial skills. The cause of this failure is the emphasis on learning geometry only on procedural and algorithmic aspects. In addition, teaching by memorizing the formulas of flat and space shapes still dominates (Lainufar et al., 2020).

Technology-based teaching is needed for an effective geometry learning (González, 2015). Dynamic geometry environment (DGE) is technology-based teaching developed to assist the teaching and learning process of geometry material. Through the implementation of DGE, students can move a line specifically to be generalized to all images (Sack, 2013). DGE has been used in mathematics classrooms in most secondary schools to train students' spatial skills in transformation of geometry material. Thus, the implementation of DGE enables students to carry out spatial activities in drawing constructivist geometric shapes. This is important so that students do not only get procedural and algorithmic knowledge.

The study of spatial abilities is inseparable from sex and gender diversities perspective. Generally, there are differences in the ability to complete geometry tasks between men and women, as reported by various mathematics education research results. The difference of capabilities in the two areas between men and women lies in three primary abilities: verbal, spatial, and arithmetic abilities (Gómez-Tone et al., 2020). Men are generally superior in spatial and arithmetic abilities, while women are usually superior in verbal skills (Zhu, 2007). Baker in Halpern (2000) argued that male superiority in spatial abilities is mainly in dynamic visual acuity. Kimura stated that men consistently show excellence in visual-spatial, such as moving and throwing targets and projectiles (Ramadas, 2009). In contrast to the study results presented above, there is no difference in the spatial ability between men and women (Putri et al., 2017); even research in the National Research Council showed that female students are more active and spatial test scores are relatively better (National Research Council, 2006).

Problem of Research

The implementation of DGE with attention to gender aspects causes a more significant influence on students' spatial abilities. This is because students are more motivated and feel more valued during the learning process (Zander et al., 2020). Several studies show that there are differences in spatial strategies in terms of egocentric and allocentric factors in the gender differences between male and female students (Chen et al., 2009; Fernandez-Baizan et al., 2019). Therefore, a perspective based on gender (other than sex) influences technology-based geometry teaching on spatial abilities more consistently. In addition, female students are often unable to read geometry maps well (Wong et al., 2018).

Research Focus

The description above shows that there are still many problems and inconsistencies in the research results on teaching geometry on spatial abilities in terms of sex and gender differences. Thus, in this study, the implementation of DGE on high school students' ability needs to pay attention to sex and gender differences to get a clearer effect. Besides, whether or not the interaction between the two (sex and gender) affects students' spatial abilities still needs further clarification.

Methodology of Research

General Background of Research

This research design used quasi-experimental quantitative to analyze DGE implementation's effect on students' spatial abilities based on sex and gender diversity. The quasi-experimental stages carried out were pre-test, teaching, and post-test. The experimental class was the group that receives the implementation of DGE with transformation geometry material.

DGE implementation was carried out for three sessions: introduction, training, and teaching of DGE. An introductory session was held for one meeting to explain the use of Geocadabra application features in DGE. The training session was also carried out for one meeting to familiarize students with using the Geocadabra application. Meanwhile, the teaching session was held for five meetings emphasizing spatial aspects, namely perception, visualization, rotation, relations, and orientation at each meeting.

Participant of Research

Target participants were determined using a purposive technique based on sex identity (male and female) and gender (masculine, feminine, androgyny and undifferentiated) (Creswell, 2012). This study involved the participation of 96 high school students in Jombang, Indonesia based on differences in sexual identity diversities, namely 48 male and female students respectively. Each of them is classified under four different gender variances.

Instrument and Procedures

The Data Collection Tools consist of a BSRI (BEM Sex Role Inventory) questionnaire and a spatial test. A BSRI questionnaire was used to collect gender data. Monto developed this instrument to determine the tendency of a person's gender characteristics, i.e., masculine, feminine, androgyny, undifferentiated (Monto, 1993).

The BSRI questionnaire consisted of 60 items with 20 items indicating gender characteristics in both masculine and feminine terms. Meanwhile, the remaining 20 items indicate gender characteristics in terms of androgyny and are undifferentiated. The validity and reliability of the BSRI questionnaire were carried out using the product-moment correlation statistical technique. BSRI questionnaire was declared valid if Sig. statistical <0.05 and positive Pearson correlation with a value of 0.02. The reliability test was carried out using Cronbach's Alpha. If the Cronbach's Alpha value > 0.60, the questionnaire or questionnaire is declared reliable or consistent (Pallant, 2001). The results of the product-moment correlation analysis were 0.002, while the results of Cronbach's Alpha analysis were 0.788. Therefore, the BSRI questionnaire was stated as a valid and reliable instrument.

Another Data Collection Tool is the spatial test. This test is used to collect data on students' spatial abilities. The spatial test used was adapted from Maier to determine students' spatial abilities (Maier, 1998). This test consists of 25 multiple-choice questions. Each of the five questions represents Maier's spatial ability elements, namely spatial perception; visualization; mental rotation; spatial relation; and spatial orientation. The validity test of the spatial test was carried out using the Product Moment statistical technique. The spatial test is declared valid if Sig. statistical <0.05 and positive Pearson correlation with a value of 0.01. The spatial test reliability test was carried out using Cronbach's Alpha. If the Cronbach's Alpha value > 0.60, the questionnaire or questionnaire is declared reliable or consistent (Pallant, 2001). The instrument is declared reliable if the Cronbach's Alpha value > 0.60. The product-moment correlation analysis results were 0.003, while the results of Cronbach's Alpha analysis were 0.912. Therefore, the spatial test is stated as a valid and reliable instrument.

Data Analysis

The data analysis used SPSS version 22.0 (IBM Corp. Released 2016) with a significance level of 0.05 to ensure that the both sexes and the four genders are comparable in spatial ability (Kirk, 1995). Data analysis used a three-way ANOVA with a 2x2x4 mixed design between the sex (male and female) and gender (masculine, feminine, androgyny and undifferentiated). Besides ANOVA, this study also used the Tukey test to determine the comparison of all pairs of treatment mean after the Variance Analysis test was carried out (Brillinger, 1984).

Results of Research

Implementation Dynamic Geometry Environment

DGE implementation was carried out in the school computer room in the experimental group. The implementation consists of three sessions, namely, introduction, training, and teaching of DGE. Each session was conducted in several meetings with a duration of 90 minutes. Although the duration may vary according to each participant as there is no time limit for activities on the worksheet. The implementation session was conducted to emphasize spatial activities aspects, namely perception, visualization, rotation, relation, and orientation at each meeting (See Figure 1). The number of response times for each participant in each session was recorded to meet the research objective, namely to determine differences in spatial abilities based on differences in sex and gender of students.

Student Spatial Ability Based on Sex Differences

The Tukey test result of sex of students' spatial abilities based on sex differences after the implementation of DGE in the experimental class is shown in Table 1.

Table 1. Tukey test result of sex

Multiple Comparisons						
Dependent Variable: spatial ability						
Tukey HSD						
(I) sex	(J) sex	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Male	Female	4.60	3.969	.048	-10.60	8.80

Table 1 shows an inferential significance value of 0.048, showing that the gender factor can affect students' spatial abilities with a difference in the mean score of 4.6, which shows the average value of men's spatial abilities is higher than the average value of women's spatial abilities. In conclusion, male students have more impact on spatial ability compared to females through DGE implementation. In the sex type variable, the value of significantly less than α (0.05), so it can be concluded that sex type also significantly impacts spatial ability. Similarly, the simultaneous interaction of sex and gender differences substantially affects students' spatial ability. This is indicated by the value of significantly less than α (0.05).

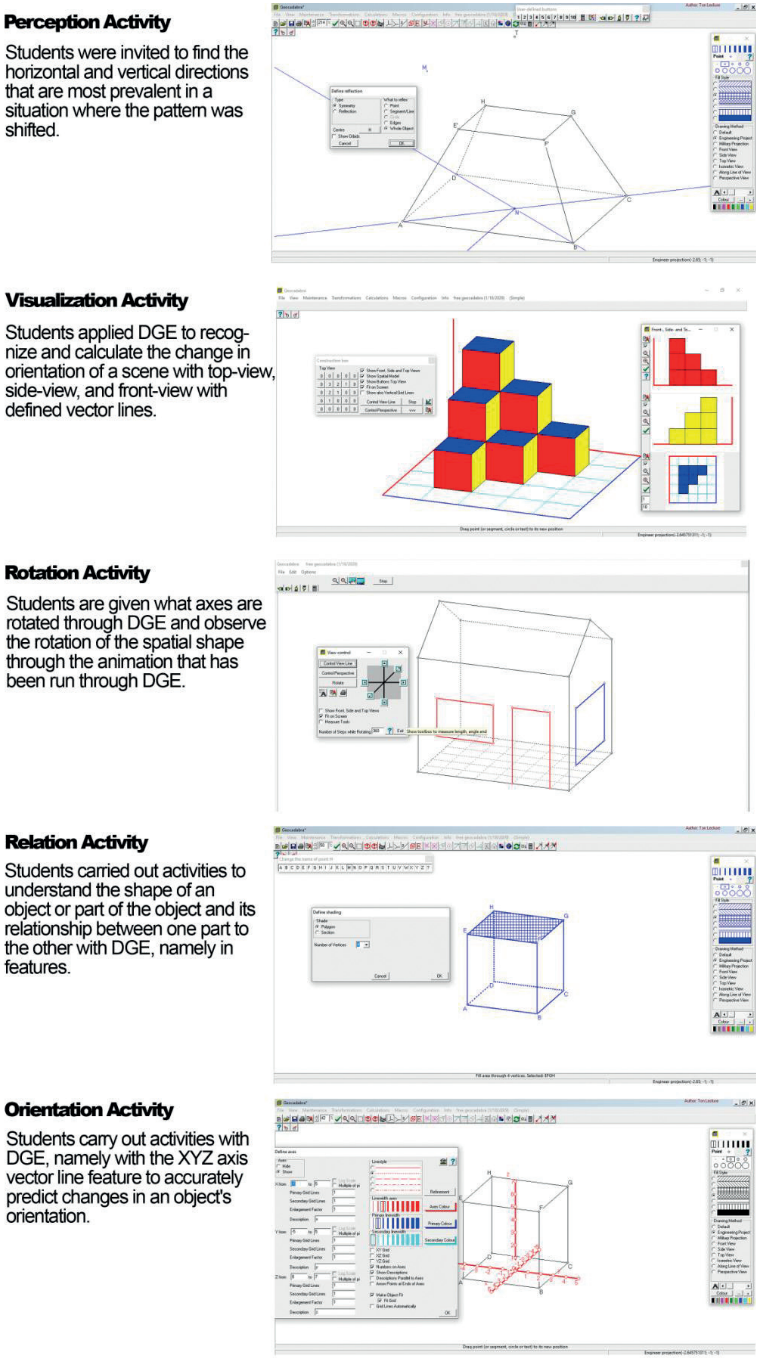

Figure 1. Activities through DGE implementation

Student Spatial Ability Based on Gender Differences

Apart from being classified by gender, the students' spatial ability tests were classified based on gender differences in the experimental class. The Tukey test result of each gender on spatial ability descriptively after DGE implementation is shown in Table 2.

Table 2. Tukey test result of gender

Multiple Comparisons						
Dependent Variable: spatial ability						
Tukey HSD						
(I) gender	(J) gender	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Masculine	Feminine	-2.80	4.060	.900	-13.80	8.20
	Androgyny	7.20	4.060	.304	-3.80	18.20
	Undifferentiated	-8.00	4.060	.220	-19.00	3.00
Feminine	Masculine	2.80	4.060	.900	-8.20	13.80
	Androgyny	10.00	4.060	.085	-1.00	21.00
	Undifferentiated	-5.20	4.060	.581	-16.20	5.80
Androgyny	Masculine	-7.20	4.060	.304	-18.20	3.80
	Feminine	-10.00	4.060	.085	-21.00	1.00
	Undifferentiated	-15.20*	4.060	.004	-26.20	-4.20
Undifferentiated	Masculine	8.00	4.060	.220	-3.00	19.00
	Feminine	5.20	4.060	.581	-5.80	16.20
	Androgyny	15.20*	4.060	.004	4.20	26.20

Based on observed means
The error term is Mean Square (Error) = 82.400

* The mean difference is significant at the .05 level

Table 2 shows a significance value of 0.048, showing that the gender factor can affect students' spatial abilities with a mean difference of 15.20. It also shows that the average value of undifferentiated gender spatial ability is higher than the average value of androgyny spatial ability. In the gender variable, the value of significantly less than α (0.05). To conclude, gender also significantly impacts spatial ability. Similarly, with the simultaneous interaction of sex and gender differences substantially affects students' spatial ability; this is indicated by the value of significantly less than α (0.05). Thus, it can be said that inferential students with undifferentiated gender have more impact on spatial abilities compared to other genders through the implementation of DGE teaching. In other words, the average score of spatial ability students with gender undifferentiated is better compared to students with feminine, masculine, dan, androgyny. This means that the implementation of DGE has more impact on spatial abilities for students who have gender undifferentiated compared to students who have feminine, masculine, and androgyny gender types.

The Effect of Sex and Gender Differences on Spatial Ability

We analyzed the data using a three-way statistical test, ANOVA (2×2×4). We used an alpha (α) level of 0.05 for all statistical tests and presented the result in Table 3.

Table 3. ANOVA test result (2×2×4)

Tests of Between-Subject Effects					
Dependent Variable: spatial ability					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4130.800[a]	7	590.114	7.162	.000
Intercept	207936.400	1	207936.400	2523.500	.000
Sex	2131.600	1	2131.600	25.869	.000
Gender	1204.400	3	401.467	4.872	.007
Sex * gender	794.800	3	264.933	3.215	.036
Error	2636.800	32	82.400		
Total	214704.000	40			
Corrected Total	6767.600	39			
R Squared = .610 (Adjusted R Squared = .525)					

Table 3 shows some significant values that can be used to sum up the results of this study. In the sex variable, a significance value less than α (0.05) is obtained, so it can be concluded that sex significantly impacts spatial ability. The impact of differences in each sex on spatial ability can be seen through differences in the average spatial ability score obtained by men and women.

Discussion

The results showed that the effect of gender differences on spatial ability came through the average score of spatial ability obtained by students in each gender through dynamic geometry environment media. This study provides a new contribution to the research on spatial ability because it discusses factors that affect students' spatial abilities, namely gender. The implementation of DGE in spatial analysis shows the differences in activity between male students and female students. It is the same as in previous research, which shows that the frequency of men's spatial ability activities is more dominant than women's spatial ability activities in implementing DGE (Maarif et al., 2018; Nagy-Kondor, 2010). This shows that DGE can determine the spatial ability activity's size in the geometric transformation concept and shows significant differences in DGE implementation based on gender.

Howard Gardner, a psychologist, suggested that one of the eight types of intelligence that humans must have is spatial intelligence, which includes spatial abilities, namely the ability to understand, process, think in visual form and translate it (Gardner, 1992). A person who has this ability can even translate images in his mind in either two or three dimensions. Students need spatial skills in studying geometry. Everyone's spatial ability is different. Many factors can influence the difference in spatial ability.

Several previous studies have contributed to the theory of sex differences on spatial abilities (Battista, 1990; Fernandez-Baizan et al., 2019; Newcombe et al., 1983). The researchers tested the factors of sex and gender differences and their interactions to see their effect on high school students' spatial abilities. Meanwhile, apart from that, the results of the study indicate the influence of gender differences on spatial ability can be seen through the average score of spatial abilities obtained by students in each gender through the application of dynamic geometry environment media. The average score of undifferentiated gender students 'spatial ability was better than the average score of masculine, feminine, androgynous gender students' spatial ability. This study provides a new contribution to the understanding which factors also affect students' spatial abilities, namely gender diversity.

Researchers used the four types of gender suggested by Bem, namely masculine, feminine, androgynous, and undifferentiated. The results of previous studies indicated that masculine and undifferentiated gender had higher spatial abilities compared to feminism and androgynous gender (Szymanowicz & Furnham, 2013). Another study showed that gender in performance was found for 3D mental rotation and spatial perception tasks, but not for spatial visualization and measured mental rotation (Reilly et al., 2016).

The results of statistical tests through three-way ANOVA showed that the variables sex and gender affect spatial ability, as well as the simultaneous interaction between sex and gender differences also significantly influence spatial ability. The effect of sex differences on spatial ability can be seen through the average spatial ability scores obtained by male and female students. This is inconsistent with the results of research, which state that men have better spatial abilities than women (Battista, 1990; Yang & Chen, 2010).

Conclusions

Based on the result discussed above, we conclude that: (1) differences in sex have an impact on the spatial ability of senior high school students; the result of the male student's spatial ability scores is better than female students; (2) differences in gender have an impact on the spatial ability of senior high school students, the *undifferentiated* student's spatial ability scores are better than students with gender *masculine, feminine,* dan, *androgyny;* (3) differences in sex and gender overall have an impact on the spatial ability of senior high school students.

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