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The Effectiveness of Learning Materials Implementation for Spatial Thinking Ability in Geographic Information Systems (GIS) Course

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***Abstract*---**Geography education is realized in learning that combines the study of physical and human geography in a spatial context. GIS Learning in universities is directed to be able to equip students in the use of spatial information which must be accompanied by the ability to manage it cognitively. This study aimed to assess the effectiveness of Spatial Thinking Ability learning materials development. The model used in this research and development study was the Dick & Carey model. The field trial was carried out by experimental research using a Quasi Experiment model. The trial design was Post-test Only, Non-Equivalent Control Group Design. The trial was carried out on sixth-semester undergraduate students at Muhammadiyah Surakarta who had taken a GIS course with as many as 41 students. The activity took place in March 2018. In this study, some students were given treatment in spatial thinking ability learning. The result shows a U value of 56 and a W value of 209. When converted to a Z value, the value is -3.943. Sig value or P-Value of 0.000 <0.05.

***Keywords*---**education, geographic information systems, geography education, learning, spatial thinking.

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Introduction

Geography education is realized in learning that combines the study of physical and human geography in a spatial context. The advantage of spatial context is that it can bring up various objects or phenomena, both physical and human aspects, together with within the scope of a certain area as complete information. Spatial information involving various phenomena or objects quantitatively and qualitatively is presented through maps with the function as data sources and learning media for Geography (Bednarz, 2004; Janko & Knecht, 2013; Jo & Bednarz, 2014; Mishra, 2013; Scholz et al., 2014). GIS Learning in universities is directed to be able to equip students in the use of spatial information which must be accompanied by the ability to manage it cognitively. The ability to manage spatial information can be done through the ability to present maps and think spatially. These two abilities are the demands of the Geography Education Study Program (S1) in preparing Geography teachers.

Geography Learning places the ability to present and explain spatial data as the main way of learning. The learning outcomes of the Geographic Information Systems (GIS) course show the weakness of students' abilities in spatial thinking even though they are already able to present maps with the national standard SNI 6502. The absence of materials, modules, and learning media for spatial thinking ability causes this problem to arise. This study aimed to assess the effectiveness of Spatial Thinking Ability learning materials development.

Method

The model used in this research and development study was the Dick & Carey model. The research methods used included performance analysis, needs assessment and instructional study. Product development was carried out by paying attention to reviews by experts—followed by an individual test, small group trials, and large group trials. The data analysis used was descriptive quantitative supported by qualitative data and a different test between the control group and the experimental group.

Field trial was carried out by experimental research using a Quasi Experiment model. The trial design was Post-test Only, Non-Equivalent Control Group Design. The trial was carried out on sixth-semester undergraduate students at Muhammadiyah Surakarta who had taken a GIS course with as many as 41 students. The activity took place in March 2018. In this study, some students were given treatment in spatial thinking ability learning (Marasri et al., 2021; Bazurto et al., 2019; Pomares et al., 2020). The test subjects were divided into two groups, namely class A as the experimental class in the implementation of learning materials for spatial thinking ability and class B as the control class. The two groups of students had never taken either spatial thinking ability learning or spatial thinking ability test before. Statistical analyses used were descriptive analysis, data normality, and Mann-Whitney U test.

Results and Discussion

The effectiveness of learning materials implementation for spatial thinking ability

The results of learning materials implementation for spatial thinking ability show that class A as the control class has an average score of 47.06 on a scale of 0-100. Meanwhile, the average score of the results of the spatial thinking ability test in Class B shows a higher number than the results in Class A, which is 71.09 or 24.03 points higher.

Table 1
Field test result of learning materials implementation for spatial thinking ability

	Class A (Control)	Class B (Experiment)
Average Score	47.06	71.09
The Highest Score	75.00	87.50
The Lowest Score	25.00	43.75

Based on the aspect of spatial thinking ability, the test results in Class A show that the spatial thinking ability that is mostly mastered by students is the spatial patterns thinking ability. About 70% of students can work on spatial patterns thinking ability. Although the lowest score in Class A questions in the overlay and graphical data visualization abilities groups, however after being grouped, Figure 1. shows that the two abilities are not the lowest (Bednarz & Lee, 2011; Golledge et al., 2008; Wallsten, 2001). Based on the order, the aspects of spatial thinking ability that are mostly mastered by students in the Control Class are spatial patterns, orientation, direction, graphic data visualization, overlay, and profiles from contour data—all of which are mastered above 50%. The 3 (three) abilities that are at least mastered by the Control Class students are a spatial association, 3D visualization of 2D data, and attribute operations.

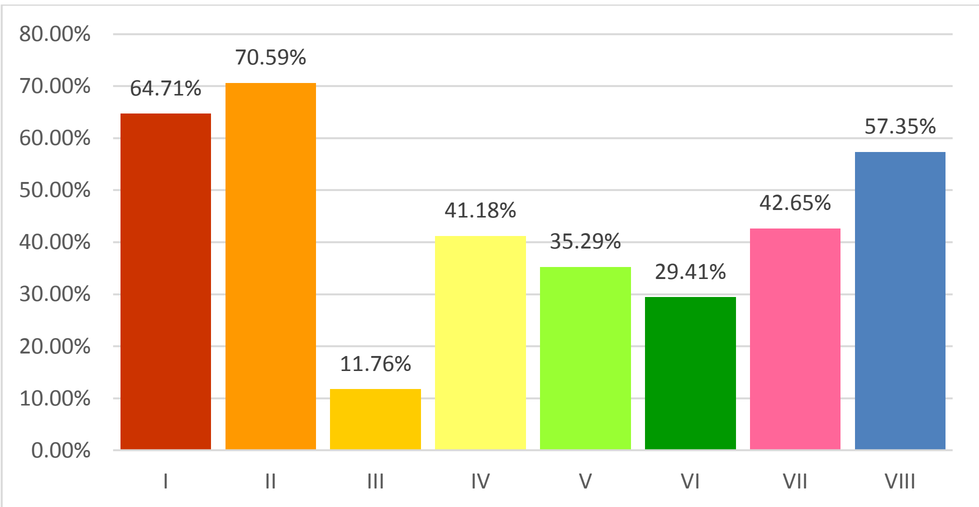

Figure 1. (Average) Percentage of control class students answering correctly 16 items of spatial thinking ability questions

Based on the aspect of spatial thinking ability, the test results in Class B show that the students' spatial thinking ability that is mostly mastered by students is the orientation and direction thinking ability (Favier & Van der Schee, 2012; Cheung et al., 2011). More than 85% of students are able to work on orientation and direction thinking ability. This is in line with the data showing the lowest score in Class B, namely the questions in attribute operations being the lowest ability. As for other abilities, it is shown in Figure 2. that students in the experimental class have mastery by 66.67% of students for spatial patterns, profiles from contour data, 3D visualization of 2D data and overlay. Graphic data visualization is mastered by 72.93% of Class B students, spatial association by 75% and orientation and direction is done correctly by 85.42% of students.

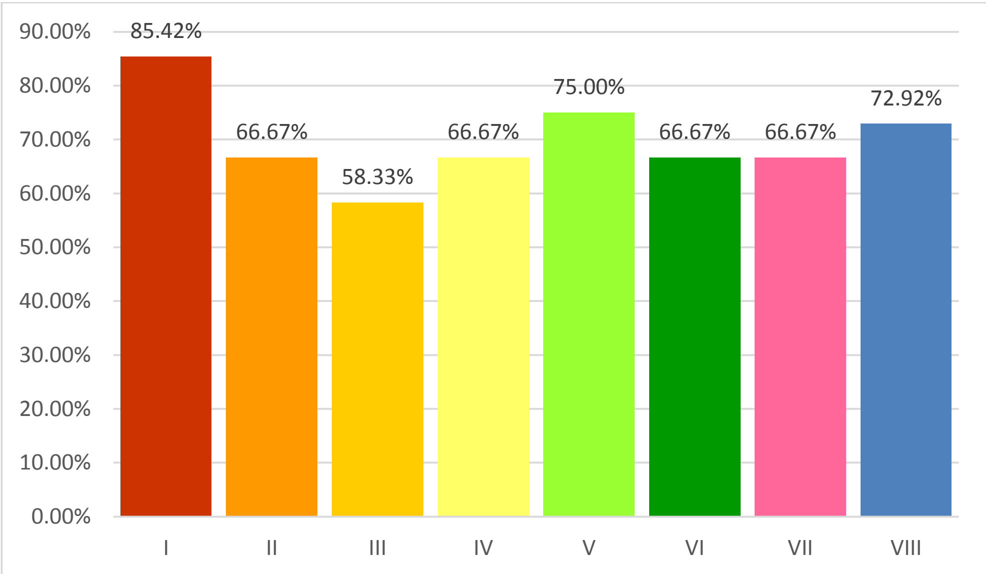

Figure 2. (Average) Percentage of experimental class students answering correctly 16 items of spatial thinking ability questions

The results of the spatial thinking ability test in class A are mostly in the poor and very poor categories, while in Class B are mostly in the moderate and good categories. The position of the groups' average is also different—wherein Class A, the average is in the poor category while in Class B, the average is in a Good category. This indicates that there is a tendency for different data between the two groups (Goodchild, 2011; Lock & Pouncett, 2017; Duizenberg, 2020).

Normality test using Shapiro-Wilk was used to see whether these two data groups, class A (control) and class B (experimental), had the same normal or different data. The results of the normality test, presented in Table 2, show that the significance value of the experimental group is 0.040, which means it is not normal. Meanwhile, the control group data show a significance value of 0.084, which is greater than 0.05. This indicates that the control group data are normal.

Table 2
Normality test results of learning materials implementation results for spatial thinking ability

Tests of Normality							
		Kolmogorov-Smirnova			Shapiro-Wilk		
	GROUP	Statistics	df	Sig.	Statistics	df	Sig.
VALUE	EXPERIMENT	0.198	24	0.016	0.913	24	0.040
	CONTROL	0.175	17	0.176	0.906	17	0.084
a. Lilliefors Significance Correction							

Because one of the group data is not normal, namely the experimental group data, it is necessary to further study the homogeneity of the data. This is to fulfill the assumption of a non-parametric difference test. If the assumption of homogeneity is fulfilled, then a different test is carried out using the Mann-Whitney U. Table 3 shows the results of the homogeneity test using Levene's test method. Levene's test is recommended because the test can be used to test the homogeneity of variance on data that are not normally distributed. The value of Levene's test is shown in the Value-Based On Mean row, with Sig (P-Value) of 0.250 > 0.05, which means that the variance of the two groups is the same or is called homogeneous. So the assumption of homogeneity to perform the difference test with the Mann Whitney U test has been fulfilled.

Table 3
Homogeneity test results of learning materials implementation results for spatial thinking ability

		Levene's Statistics	df1	df2	Sig.
VALUE	*Based on Mean*	1.366	1	39	.250
	Based on Median	.951	1	39	.335
	Based on Median and with adjusted df	.951	1	37,817	.336
	Based on trimmed mean	1.349	1	39	.253

Table 4. shows a U value of 56 and a W value of 209. When converted to a Z value, the value is -3.943. Sig value or P-Value of 0.000 <0.05. If the P-Value < critical limit of 0.05, then there is a significant difference between the two groups—which means that the learning materials implementation for spatial thinking ability provides a significant difference in the results of students' spatial thinking ability.

Table 4
Different test results of learning materials implementation for spatial thinking ability

Test Statistics	
	MARK
Mann-Whitney U	56.000
Wilcoxon W	209.000
Z	-3.943
Asymp. Sig. (2-tailed)	.000
a. Grouping Variable: GROUP	

The results of the different test indicate that the development of learning materials for spatial thinking ability has fulfilled the requirements for use. It appears that the product of this research and development of learning materials for spatial thinking ability provides a real (significance) difference. This difference is indicated by the ability to think spatially, which is much better than the group that does not take part in learning that implements spatial thinking ability (Goodchild & Janelle, 2010; Lee & Bednarz, 2012; Lefebure, 2019).

However, the results of the field test show that GIS learning which has been directed at making maps according to SNI standards has equipped some students' abilities in spatial thinking. In both experimental and control classes, the ability to think spatially in the form of orientation and direction, spatial patterns, and visualization of graphic data seems to have been mastered by most of the students from the results of previous GIS learning. For example, mastery of orientation and direction ability is related to assignments in map presentation that must arrange map orientation according to the description of the relationship between GIS and spatial ability. GIS learning affects spatial thinking ability even though it depends on the lecture material and practice (Lee & Bednarz, 2009).

The results of the field test using a quasi-experimental model in the learning materials implementation for spatial thinking ability are one way to develop spatial thinking ability in Geography Education students. The role of other researchers is needed to strengthen the development of spatial thinking ability through various approaches. One that is considered is to conduct an experiment using a control group (Golledge & Stimson, 1997). The results of the effectiveness test show conformity with the results of the performance analysis which shows that students are still limited in using spatial thinking ability in the thesis. The results of the performance analysis show that students, so far, only use 2 (two) aspects, namely orientation and direction and graphical data visualization. The results of the field test show that students who did not take part in learning using learning materials for spatial thinking ability mastered 3 (three) aspects, namely orientation and direction, visualization of graphic data, and spatial patterns. These three aspects, as shown in Figures 1 and 2, have a score of more than 56 to 71, meaning that students are categorized as having spatial thinking ability in these three aspects, having a moderate to good mastery category (Kirby et al., 2017; Bastian et al., 2002; Meadows, 2020).

The findings above indicate that learning spatial thinking ability in GIS with top-down cognitive processes results in limited mastery of spatial thinking ability. Top-down cognitive processes result in mastery of only three aspects. Significantly different from learning spatial thinking ability using a combination of bottom-up and top-down cognitive processes which results in mastery of all aspects of spatial thinking ability, as shown in Figure 2, having a moderate to good mastery category (Basso et al., 2000; Wakabayashi & Ishikawa, 2011; Widana et al., 2020).

This research and development study has succeeded in finding that the implementation of a combination of bottom-up and top-down processes in GIS learning has a real impact on the mastery of all aspects of spatial thinking ability. The impact of GIS learning on spatial thinking ability can be proven significantly by implementing spatial thinking ability learning materials. In previous studies, the belief in the impact of GIS learning on students' spatial thinking ability has been shown to make a difference, but it has not been proven for its significance (Albert & Golledge, 1999; Lee & Bednarz, 2009). This is due to the implementation of top-down cognitive processes in the old GIS learning. Based on the findings in this research and development study, GIS learning must be changed to the implementation of a combination of bottom-up and top-down cognitive processes by implementing learning materials for spatial thinking ability.

Conclusion

The development of learning materials for spatial thinking ability has fulfilled the requirements for use. Students who get the spatial thinking ability materials have a much better spatial thinking ability than those who do not take part in learning that implements spatial thinking ability.

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