JSSER
www.jsser.org
Journal of Social Studies Education Research
Sosyal Bilgiler Eğitimi Araştırmaları Dergisi
2024:15 (1), 251-281

Developing Spatial Thinking through the Earthcomm Learning Model: Exploring the Role of Earth Science in the Community

Muhammad Aliman[1], Sumarmi[2] & Silvia Marni[3]

Abstract

The purpose of this study is to determine the spatial thinking ability of high school students using indicators from Sharpe-Huynh model. These indicators include analysis, spatial interaction, scale, representation, comprehensiveness, and application. Furthermore, this study examined the effect of Earthcomm learning on student's spatial thinking ability. This study research employs a quantitative study, utilizing a quasi-experimental design with a non-equivalent control group. The study is conducted among school students in Padang City, West Sumatera Province, Indonesia. The research population consisted of 287 students, divided into eight research groups. Data on students' spatial thinking ability were collected through the Sharpe-Huynh model of spatial thinking ability test. Before further analysis, the data were assessed for normality and homogeneity. The experimental group utilized earth science in the community (Earthcomm) learning model, while the control group employed conventional learning. The research data were analyzed using Mann-Whitney U test. The findings revealed that the spatial thinking ability of high school students ranged from low to moderate. The Earthcomm learning model demonstrated a significant impact in improving spatial thinking skills. The impact of Earthcomm learning on enhancing spatial thinking abilities among high school students is elaborated in the following article.

Keywords: *Earthcomm learning, geography learning, spatial thinking.*

Introduction

A comprehensive exploration of geography education should inherently include spatial thinking (Hammar et al., 2021). Spatial thinking ability refers to an individual's capacity to comprehend and integrate spatial objects through spatial concepts, representational tools, and cognitive processes (Aliman et al., 2019). Spatial thinking abilities are critical for surviving in the millennium era (Flynn, 2018). Furthermore, spatial thinking plays a pivotal role in enabling successful STEM learning (Johnson & McNeal, 2021; Uttal & Cohen, 2012). Spatial thinking skills also play a major role in supporting students' proficiency in learning geography (Gold et al., 2018). However, spatial thinking abilities often do not receive primary emphasis in geography

---

[1] *Dr. Universitas Negeri Malang, Indonesia, Email: alviageo@gmail.com*
[2] *Prof. Dr. Universitas Negeri Malang, Indonesia, Email: sumarmi.fis@um.ac.id*
[3] *Dr. Universitas PGRI Sumatera Barat, Indonesia, Email: silv1a@upgrisba.ac.id*

education (Juliasz, 2021; Kim & Bednarz, 2013). This is evidenced by students' deficiency in spatial thinking abilities, particularly geographic literacy skills (Imaniar et al., 2021; Kamil et al., 2020; Metoyer & Bednarz, 2017; Nhlumayo & Mofokeng, 2023; Sudatha et al., 2018; Utami & Zain, 2018). The lack of spatial thinking aspects in geography textbooks is the cause of the low in spatial thinking ability of high school students (Ridha et al., 2019).

Even in the past 50 years, the research of spatial thinking has progressed by only 8% (de Queiroz, 2021). The limited spatial thinking among students has been linked to low geography learning outcomes (Amin et al., 2020; Nhlumayo & Mofokeng, 2023). Spatial thinking skills are aimed at assisting students in understanding environmental conditions and solving environmental issues (Purwanto et al., 2021). Upon entering their career, students can leverage their spatial thinking abilities to effectively utilize geospatial technologies (Alajmi, 2021; Metoyer & Bednarz, 2017; Wijayanto et al., 2023), including determining regional spatial planning policies (Boonen et al., 2014; Hammar et al., 2021).

Spatial thinking abilities can be improved through training and educational approaches designed to support these skills among high school students (Aliman et al., 2019). Various research has investigated the effectiveness of learning geography and earth in increasing spatial thinking abilities and geographic literacy. These research efforts encompass diverse approaches such as the application of Web GIS Learning (Kim & Bednarz, 2013; Santoso et al., 2021), learning geography for enhancement of geographic literacy (Kamil et al., 2020; Zid & Casmana, 2021), earth science in the community (Earthcomm) learning in increasing environmental awareness of high school students (Prastiyono et al., 2021), improving spatial ability and geography learning outcomes through problem-based hybrid learning (Amin et al., 2020), Earthcomm learning in developing high school students' motivation and spatial abilities (Hidayat et al., 2017), geographic literacy in improving high school students' spatial intelligence (Utami & Zain, 2018), outdoor study learning in improving students' spatial thinking abilities (Aliman et al., 2019). However, research pertaining to the utilization of Earthcomm learning to enhance high school students' spatial thinking abilities remains limited. Therefore, this study aimed to determine the effect of Earthcomm learning on the spatial thinking skills of high school students.

Research questions

What is the impact of Earthcomm learning on spatial thinking abilities as assessed through indicators like analysis, representation, scale, application, spatial interaction, and comprehensive?

Hypothesis

The hypotheses presented in this study are formulated based on the research questions as follows:

H0 = There is no significant difference in students' spatial thinking ability based on indicators such as analysis, representation, scale, application, spatial interaction, and comprehensiveness when exposed to Earthcomm learning.

H1 = There are significant differences in Earthcomm learning concerning students' spatial thinking ability, as indicated by the analysis, representation, scale, application, spatial interaction, and comprehensive

Literature Review

Spatial Thinking

Spatial thinking entails human reasoning's capacity to participate in complex cognitive processes involving spatial phenomena on earth (Aliman et al., 2019; Bednarz, 2015). Cognitive abilities used in spatial thinking have been developed by several experts. Furthermore, indicators of spatial thinking encompass analysis, spatial interaction, scale, comprehensiveness, application, and representation (Huynh & Sharpe, 2013). Cognitive abilities can systematically develop every day through a number of lessons, particularly in the field of geography (Juliasz, 2021; Polat, 2020). Teachers can acquire and foster spatial thinking abilities through the study of geography (Pilato et al., 2023). One approach to facilitating this development involves integrating student activities within the classroom, laboratory, and practical experiences in their surrounding environment (Cortés Loyola et al., 2020).

Furthermore, the taxonomy of spatial thinking has been expanded to encompass spatial representation, spatial reasoning and spatial concepts (Jo et al., 2010). However, this study employed the indicators of spatial thinking from the Sharpe and Huynh model due to their intricate nature, making them suitable for potential development into spatial thinking test instruments.

Earthcomm Learning

Many geography lessons have the potential to enhance spatial thinking abilities and geographic literacy, including outdoor learning (Prastiyono et al., 2021), earth science in the community (Earthcomm) (Carpenter & Hoover, 2019; Hidayat et al., 2017), utilizing large travel maps (Fleming & Mitchell, 2017), learning geography literacy (Kamil et al., 2020; Utami & Zain, 2018), engaging in experiential based learning (Flynn, 2018), employing short online learning and exercises (Gold et al., 2018), utilizing GIS learning (Kim & Bednarz, 2013; Mkhize, 2023), implementing PBL-GIS (Romadlon et al., 2021), incorporating augmented reality (AR) sandbox (Johnson & McNeal, 2021).

Among the methods for developing spatial thinking abilities in geography, earth science in the community (Earthcomm) learning model offers several advantages over alternative methods. Earthcomm learning surpasses other learning methods due to its emphasis on the experiential process that students undergo (Hidayat et al., 2017; Prastiyono et al., 2021; Ningrum & Kholiq, 2018). Earthcomm learning not only evaluates students within the cognitive domain, but also assesses their problem-solving skills (Carpenter & Hoover, 2019). Moreover, Earthcomm learning empowers students to collaboratively establish assessment criteria (Aliman et al., 2019; Hidayat et al., 2017).

Earthcomm learning can be implemented in schools located in non-urban areas (Park, 2001) and is not dependent on internet access such as learning short online learning (Gold et al., 2018). A challenge associated with Earthcomm learning the demand for additional time, as it involves learning both inside and outside the classroom (Aliman et al., 2019; Carpenter & Hoover, 2019).

Earthcomm learning was formulated under the constructivism paradigm, centering on cultivation of students' comprehension through learning experiences (Aliman et al., 2019; Park, 2001).

Along with the constructivism paradigm, the challenge, think about it, and investigation sessions reinforce the cognitivism paradigm by requiring students to utilize their cognitive abilities for problem-solving and conducting investigations (Polat, 2020). During the investigative learning stage, where students delve deeper and inquire extensively, they can acquire indirect exposure to problem identification and resolution. This can heighten students' awareness and concern regarding issues within their immediate environment (Amin et al., 2020).

These learning stages also align with the behaviorism paradigm established by Edward Thorndike, as they emphasize the cultivation of positive attitudes and behavior formation (Mc Leod, 2018).

Examining the correlations among educational models unveils the potential of Earthcomm learning to enhance students' spatial thinking abilities within a theoretical framework.

Spatial thinking skills can flourish when geography education transcends mere theoretical instruction and actively engages students in diverse fieldwork and assignments, employing GIS to acquaint them with their local environment (Mkhize, 2023a; 2023b).

Method

Research Design

This study employs a quantitative research approach, utilizing a quasi-experimental design with a pretest and posttest control group design model. The independent variable is the Earthcomm learning model, and the dependent variable is spatial thinking abilities, consisting of six indicators: analysis, comprehensiveness, spatial interaction, scale, representation, and application. Analytical abilities empower students to investigate natural phenomena and their interactions with human activities. Representation ability involves the skill to decipher diverse symbols on maps, aerial photographs, and satellite images.

The development of comprehensive ability necessitates students' capacity to identify relationships, patterns, and interactions among different natural events, enabling them to formulate conclusions. Application ability entails using technology or software to conduct observations, surveys, and interpretations of maps, aerial images, and satellite photos. Scale pertains to the skill of measuring and comparing patterns, forms, similarities, and differences among natural events.

Spatial interaction ability pertains to the cognitive capability of analyzing and comprehending the relationships among different natural events. This capability encompasses recognizing the primary causes and effects of these phenomena, along with assessing the pros and cons associated with their relationships (Huynh & Sharpe, 2013). The research outline is illustrated in Figure 1 below.

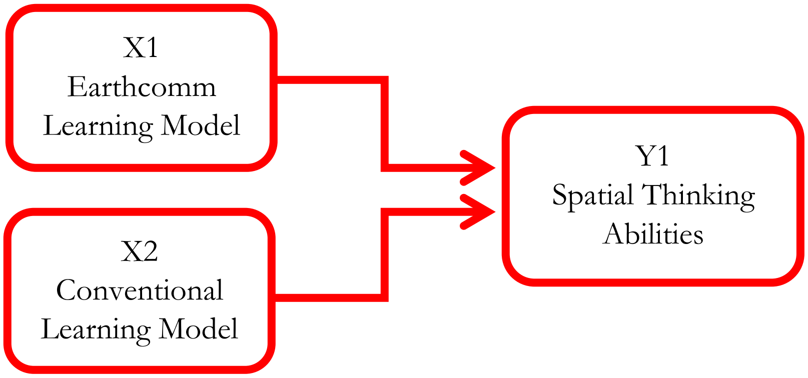


Figure 1. Research Flowchart

Notes:

X1 = Earthcomm learning model
X2 = Conventional learning model
Y1 = Spatial thinking abilities

Table 1

Experimental Class and Control Class Research Design

Pretest	Group	Posttest
O1	X1 - Y1	O2
O3	X2 - Y2	O4

Notes:

O1, O3= Pretest (spatial thinking ability)
O2, O4= Posttest (spatial thinking ability)
X1 = Earthcomm learning model (experiment class)
X2 = Conventional learning model (control class)
Y1 = Class X IIS 3
Y2 = Class X IIS 2

Experimental research applies Earthcomm learning in the experimental group and conventional learning in the controlled group. The test instrument was developed using spatial thinking indicators as outlined by Huynh and Sharpe (2013), which were subsequently developed by the researchers into 18 questions.

The instrument utilized to measure spatial thinking abilities requires evaluation for validity and reliability evaluation both before the pretest and posttest. The spatial thinking ability instrument consists of 18 questions, categorized by indicators: Analysis (4 questions), Comprehensive (4 questions), Application (4 questions), Spatial Interaction (2 questions), Scale (2 questions), and Representation (2 questions).

The instrument underwent initial content validity testing by an expert in geography education from the Malang State University, Indonesia. The instrument derived from the six indicators is subsequently assessed by an expert using the following assessment criteria:

The assessment included evaluating the alignment between the indicators and the item grid and items, ensuring compatibility between the test items and the level of cognitive thinking, verifying compatibility between the questions and high-order thinking skills, the compatibility between the questions and the environment of students, confirming the accuracy of concepts presented in the questions, maintaining language consistency with guidelines while maintaining communicative effectiveness, and ensuring clarity of sentence interpretation to prevent miscommunication among students.

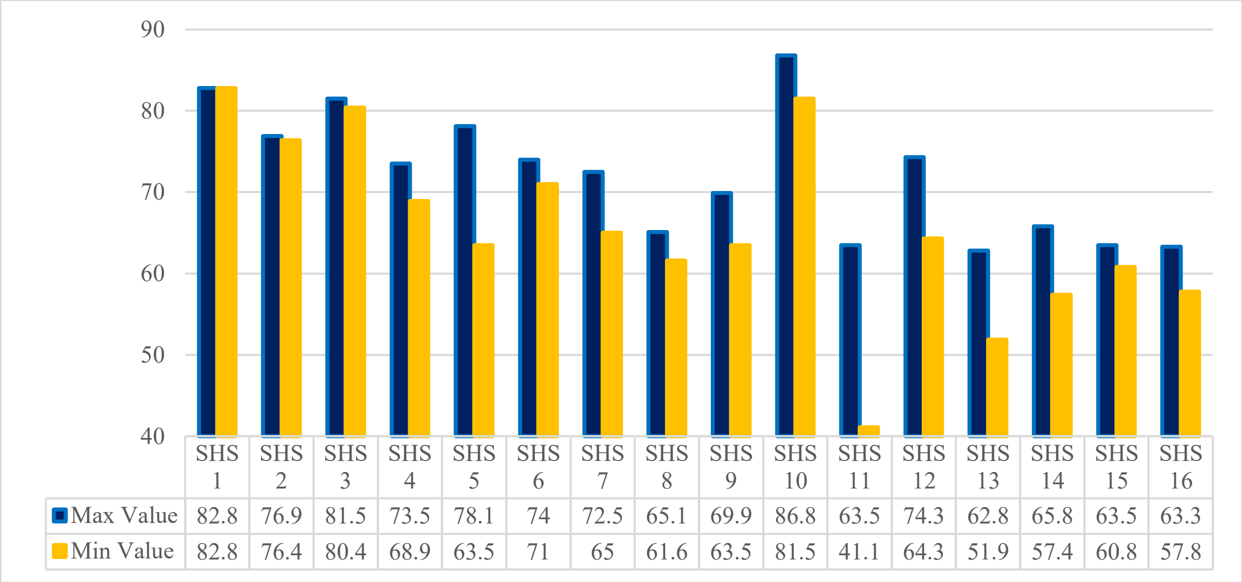
The assessment conducted by the expert confirmed validity of the instrument in validity in effectively collecting data pertaining to students' spatial thinking abilities. Afterward, the instrument's reliability was evaluated with 75 students, yielding a Cronbach's alpha score of 0.735. This score signifies that the instrument is dependable for utilization within the research group.

Study Sample

The research subject is public high school students in the city of Padang, West Sumatra Province, encompassing a total of 16 schools. These schools employ a selection method based on the average entrance test scores for high school students, as determined by national standardized test scores. Participants are provided the opportunity to choose three schools through an online selection process. In the first option, students are arranged based on their average test scores, subsequently ranked and adjusted according to capacity.

If the participant does not succeed in their first school choice, they are considered for the second school choice, and if needed, for the third school choice. Participants who do not succeed in these three choices are then provided the opportunity to opt for a private high school.

Derived from the selection process, the average outcomes of the selection for 2019 high school class X students are presented in Figure 2.



	SHS 1	SHS 2	SHS 3	SHS 4	SHS 5	SHS 6	SHS 7	SHS 8	SHS 9	SHS 10	SHS 11	SHS 12	SHS 13	SHS 14	SHS 15	SHS 16
■ Max Value	82.8	76.9	81.5	73.5	78.1	74	72.5	65.1	69.9	86.8	63.5	74.3	62.8	65.8	63.5	63.3
■ Min Value	82.8	76.4	80.4	68.9	63.5	71	65	61.6	63.5	81.5	41.1	64.3	51.9	57.4	60.8	57.8

Figure 2. Student's Maximum and Minimal Score to be Accepted in Senior High School (SHS) at Padang City

Figure 2 displays the highest and lowest scores achieved in national exam by senior high school students in Padang city. The senior high schools that admitted students with intermediate exam scores ranging from 63 to 65 were SMAN 11 Padang, SMAN 13 Padang, SMAN 14 Padang, SMAN 15 Padang, and SMAN 16 Padang. Among these, SMAN 15 Padang exhibited the smallest gap score in comparison to all the other senior high schools included in this study, with a gap score of 2.07. This suggests that students possess relatively similar overall abilities.

The initial criterion for evaluating the homogeneity of the research sample is the similarity in abilities among the students. Therefore, SMAN 15 Padang was selected as the research location. The research population comprised 287 students from grade 10 (grade X) of SMAN 15 Padang (Public Senior High School), West Sumatra Province, Indonesia. The students were selected from a total of eight classes.

Furthermore, two classes (X IIS 2 and X IIS 3) were selected as the research sample employing purposive sampling technique. Students from these classes exhibit similar abilities, particularly in geography learning outcome. The s learning outcome scores of students at SMAN 15 Padang are detailed in Table 2.

Table 2
Average Geography Learning Outcomes of Grade X Students in SMAN 15 Padang

Class	Gender		N	Average geography learning outcome	Research group
	Male	Female			
X MIA 1	15	21	36	87.69	-
X MIA 2	13	23	36	84.73	-
X MIA 3	11	24	35	86.29	-
X MIA 4	16	20	36	81.85	-
X MIA 5	18	18	36	85.61	-
X IIS 1	20	16	36	78.21	-
X IIS 2	18	18	36	79.24	Control
X IIS 3	21	15	36	79.89	Experiment
Total	132	155	287	82.94	-

Notes:

X MIA = Grade X science class
X IIS = Grade X social class

According to Table 2, the average geography learning outcomes of students at SMAN 15 Padang is 82.94. The classes with the most notable variations in average geography learning outcomes were class X IIS 2 and class X IIS 3. The two classes, which were assessed to have slightly different outcomes in geography learning, were considered to have the same cognitive ability. This suggests that the two classes exhibit similarity in terms of geography learning outcome.

Data Collection Tools

Data collection techniques in this study involve the use of tests, which include a pretest and a posttest. These tests are designed in the format of a spatial thinking test instrument. The researcher utilizes Google Form to gather data for both the pretest and posttest. The test instrument was distributed among a total of 72 students with 36 in the control class and 36 in the experimental class. Students were allocated 60 minutes as the time limit to complete the test instrument.

The researchers implemented measures to minimize any interference from external factors in the classroom during data collection for the pretest and posttest. The Sharpe-Huynh model was tested for the validity and consistency (Aliman et al., 2019). Moreover, the instrument can serve to gather pretest and posttest data from research participants in both the experimental and control groups.

Data Analysis

The pretest and posttest values of spatial thinking skills were subsequently tested for normality and homogeneity using SPSS software. The normality test was performed to identify the distribution of data within the study group. The independent t-test analysis can be used when the data follows a normal distribution in parametric tests. Mann-Whitney U test analysis serves as a non-parametric alternative for data with irregular distribution. Subsequently, a homogeneity test is employed to assess data distribution variance.

Research Process

The study was conducted within two groups: which underwent conventional learning, and the experimental group, which adopted Earthcomm learning. Students in both the control and experimental groups receive instruction from the same teacher and are closely monitored by researchers to ensure alignment between their learning and the syntax of the Earthcomm learning model, as well as conventional learning models.

After each session, teachers and researchers partake in discussions and reflective activities concerning the learning process. Conventional learning involves methods such as lectures, question and answer sessions, discussions, and presentations. Also, Earthcomm learning applied learning steps illustrated in Figure 3.

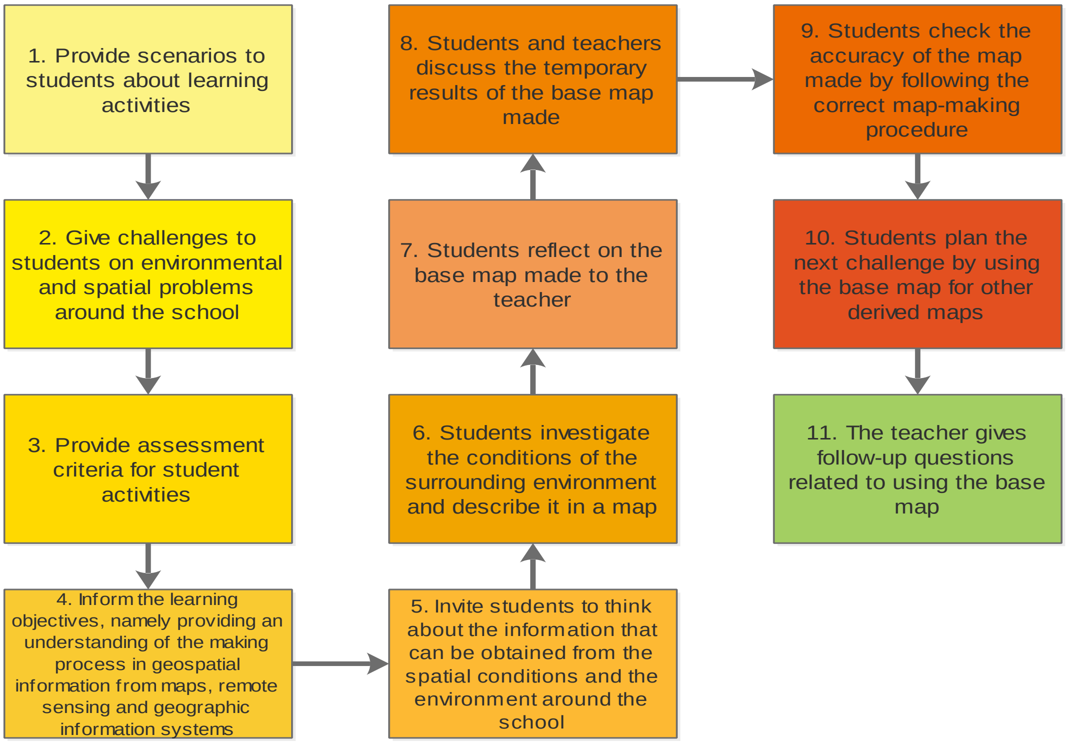


Figure 3. Stages of Learning Earthcomm (Source: Author's modification, 2022)

The stages of experimental research are shown in Table 3.

Table 3

Learning Activities in Experimental Group and Control Group

	Learning Meeting														
Week		1			2			3			4			5	
Learning Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Activity	O_1	Experimental													O_2
	O_1	Control													O_2

Information:

O_1 = Spatial thinking ability assessment (pre-test)
O_2 = Spatial thinking ability assessment (post-test)

Public Senior High Schools in Indonesia are categorized into three grades. The initial year is referred to as class X, the second year as class XI, and the final year as class XII. Furthermore, the school divided the study program into IIS or social study program and MIA or science study program. Earthcomm learning was implemented in class X IIS 3, while conventional learning was employed in class X IIS 2.

This research was conducted over a span of five weeks, from September 3, 2019, to October 6, 2019. The study focused on the geography subject, specifically covering fundamental concepts of mapping, remote sensing, and geographic information systems. Each lesson lasted for 135 minutes.

Results

Spatial Thinking Ability

Both the controlled and experimental groups were administered the same spatial thinking ability test, which had been validated prior to the implementation of Earthcomm learning and conventional learning. Each question in the test carried a maximum score of 4 and a minimum score of 0.

The allocated time for completing the test is 60 minutes, and it consists of 18 questions. The pretest and posttest scores of students' spatial thinking abilities are presented in Table 4.

Table 4

Pretest and Posttest Results of Spatial Thinking in Research Groups

Indicator of spatial thinking	Class	Pretest	Post-test	Improvement	
				Score	%
Analysis	Control	1.370	2.074	0.704	51,39
	Experiment	2.107	2.571	0.464	22,02
Comprehensive	Control	1.259	1.963	0.704	36,85
	Experiment	1.929	2.321	0.393	20,37
Application	Control	2.037	2.630	0.593	29,11
	Experiment	2.286	3.357	1.071	46,85
Spatial Interaction	Control	0.407	1.037	0.630	154,8
	Experiment	1.107	1.857	0.750	67,75
Scale	Control	1.037	1.148	0.111	10,70
	Experiment	0.714	1.607	0.893	125,1
Representation	Control	1.148	1.889	0.741	64,54
	Experiment	1.143	2.500	1.357	118,7

Table 4 shows that the pretest and posttest, each contain six indicators of spatial thinking. Analyzing the data presented in Table 2 shows a noticeable rise in the values of each indicator, observed between the pretest and posttest. The improvement section displays the scores and percentage components. The six indicators of spatial thinking developed by Huynh and Sharpe (2013) effectively gauge the thinking ability of high school students.

This test was developed by tailoring it to the cognitive abilities of high school students. Drawing from Piaget's theory, students aged 14-17 are considered to have reached the formal operational stage, encompassing spatial thinking and attaining abstract and logical thinking skills (Bond, 2005). In the experimental class, both the scale and representation indicators exhibited a significant average score increase. The Scale indicator demonstrated a rise of 0.893, translating to a 125.1% increase between pretest and posttest scores.

The representation indicator displayed an increase of 1.357, reflecting a 118.7% increase between pretest and posttest scores. Additionally, within the experimental group, the Comprehensive indicator of spatial thinking showed a minor improvement in average score.

The comprehensive indicator's average score in the experimental class saw an increase of 0.393, equivalent to a 20.37% improvement. The comparison of average scores across the indicators between the experimental and control groups is illustrated in Figure 4.

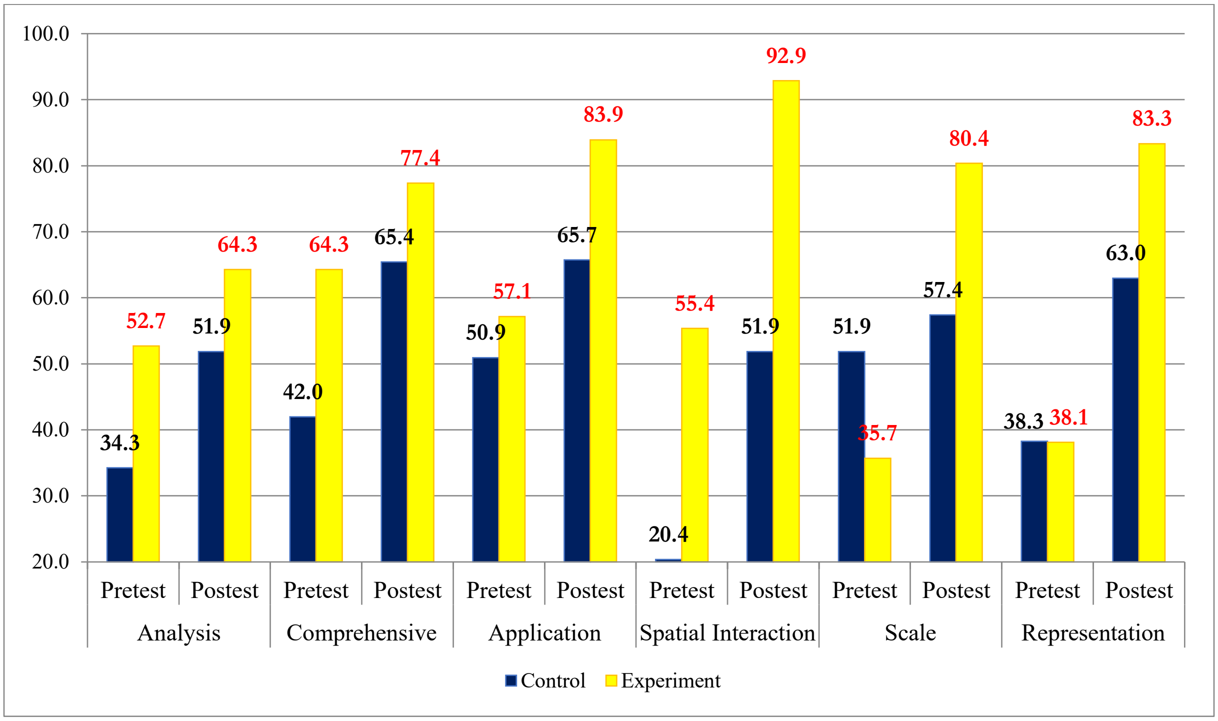


Figure 4. Comparison of Pretest and Posttest Scores Based on Spatial Thinking Indicators

As depicted in Figure 4, a comparison was made between the scores of each spatial thinking indicator during the pretest and posttest for both research groups. In the pretest phase, the control group exhibited the lowest average score among spatial thinking indicators, which was 20.4.

In the control group, the Application indicator achieved the highest average score of 51.9, whereas in the experimental group during the pretest, the Scale indicator attained the lowest average score of 35.7. During the pretest, the comprehensive indicator recorded the highest average score within the experimental group, reaching a value of 64.3.

Following the posttest, the Analysis and Spatial Interaction indicator recorded the lowest average score of 51.9 in the control group, whereas the application indicator achieved the highest average score of 65.7 in the same group.

In contrast, within the experimental group during the posttest, the analysis indicator demonstrated the lowest average score, at 64.3. Conversely, the highest average score among spatial thinking indicators for the experimental class during the posttest was achieved by the Spatial Interaction indicator, with a value of 92.9.

Normality Test

A normality test was conducted on the spatial thinking ability test performed during the pretest and posttest to determine whether the distribution of results was normal or not. This test helps measure the extent to which the received data differs significantly from the ideal normal distribution. The outcomes of the normality test are presented in Table 5.

Table 5

The Result of Normality Test of Spatial Thinking Ability

Indicator of spatial thinking	Sig.							
	Kolmogorov-Smirnov				Shapiro-Wilk			
	Control		Experimental		Control		Experimental	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Postest
Analysis	.000	.004	.000	.000	.001	.016	.002	.002
Comprehensive	.000	.000	.000	.000	.001	.000	.000	.000
Application	.071	.005	.000	.000	.046	.004	.006	.000
Spatial Interaction	.000	.000	.000	.000	.000	.000	.000	.000
Scale	.000	.000	.000	.000	.000	.000	.000	.000
Representation	.000	.000	.000	.000	.000	.000	.001	.000

Table 5 displays the normality results of the average score of students' spatial thinking abilities in the two research groups. Specifically, the application indicator demonstrated normal scores solely during the pretest, while the Analysis indicator was exclusively used during the posttest in the control class. Overall, the scores of spatial thinking indicators did not exhibit a normal distribution ($p < 0.05$). Consequently, the Mann-Whitney U test will be employed for the subsequent analysis.

Homogeneity Test

A homogeneity test is employed to ascertain whether there are significant differences between the two scores of the spatial thinking test. The outcomes of the homogeneity test are presented in Table 6.

Table 6

Homogeneity Test of Spatial Thinking Indicators

Indicators	Levene Statistic	df1	df2	Sig.
Analysis	.018	1	53	.894
Comprehensive	4.517	1	53	.038
Application	17.472	1	53	.000
Spatial Interaction	1.250	1	53	.269
Scale	.461	1	53	.500
Representation	1.852	1	53	.179

As per Table 6, only the application indicator is not homogenous, with a p-value less than 0.05. However, the other indicators namely analysis ($p = 0.894 > 0.05$), comprehensive ($p = 0.038 > 0.05$), spatial interaction ($p = 0.269 > 0.05$), scale ($p = 0.500 > 0.05$), and representation ($p = 0.179 > 0.05$) are found to be homogeneous ($p > 0.05$). Following the assessment of normality and homogeneity tests, the Mann-Whitney U test was employed to determine the difference between the application of Earthcomm and conventional learning to spatial thinking abilities.

Earthcomm Learning on Spatial Thinking Abilities

In line with the proposed hypothesis, it asserts a relationship between the Earthcomm learning model and students' spatial thinking abilities. The subsequent section furnishes an in-depth analysis of the research findings, focusing on the six spatial thinking indicators.

The Effect of Earthcomm Learning on Analysis Ability

As outlined by Sharpe dan Huynh (2013), analysis constitutes a vital component of spatial thinking skills. It holds significance to compare Earthcomm learning to conventional teaching in order to evaluate the impact on students' analytical abilities.

The following hypothesis pertains to the influence of Earthcomm learning on analytical skills.

H0 = There is no significant difference between Earthcomm learning and students' spatial thinking ability based on indicators analysis.

H1 = There are significant differences between Earthcomm learning and students' spatial thinking ability based on indicators analysis.

The results of Mann-Whitney U test are displayed in Table 7.

Table 7

Mann-Whitney Results in Analysis Indicator

	Analysis
Mann-Whitney U	267.000
Wilcoxon W	645.000
Z	-1.987
Asymp. Sig. (2-tailed)	.047

According to the Mann-Whitney U test results in Table 7, a 2-tailed significance score of 0.047 was obtained, which is lower than 0.050. These findings indicate a significant difference in the analysis indicator between the experimental group and the control group.

This difference is further evident in the posttest results of the experimental group, which surpass those of the control group. The average score of the experimental group, implementing Earthcomm learning, reached 64.3, compared to the control group's average score of 51.9, employing conventional learning (Figure 4). The results of the Mann-Whitney U test presented in Table 7 confirm that H1 hypothesis is accepted and the H0 hypothesis is rejected. This indicated that the Earthcomm learning model has an effect on students' spatial analysis abilities.

The Effect of Earthcomm Learning on Comprehensive Ability

Determining the effect of Earthcomm learning on students' comprehensive abilities required a comparison with traditional learning. The following hypothesis addresses the impact of Earthcomm learning on comprehensive skills.

H0 = There is no significant difference between Earthcomm learning and students' spatial thinking ability based on indicators comprehensive.

H1 = There are significant differences between Earthcomm learning and students' spatial thinking ability based on indicators comprehensive.

The comparison of scores for comprehensive indicators between Earthcomm learning and conventional teaching is presented in Table 8.

Table 8

Mann-Whitney Results in Comprehensive Indicator

	Comprehensive
Mann-Whitney U	266.500
Wilcoxon W	644.500
Z	-2.107
Asymp. Sig. (2-tailed)	.035

As per the data in Table 8, the Mann-Whitney U test results for the comprehensive indicator yielded a 2-tailed significance value of of 0.035, which is less than 0.050. This indicates a significant difference in the comprehensive indicator between the experimental group and the control group. This difference is similarly evident in the posttest results of the experimental group, where the scores are higher compared to the control group. The average score of the experimental group, implementing Earthcomm learning, reached 77.4.

Meanwhile, the control group, which utilized conventional learning, achieved an average score of 65.4 (Figure 4). The results of the Mann-Whitney U test presented in Table 8 affirm the acceptance of the H1 hypothesis is accepted and the rejection of the H0 hypothesis. This implies that the Earthcomm learning model has an impact on students' spatial comprehensive abilities.

The Effect of Earthcomm Learning on Application Ability

The effect of Earthcomm learning on application abilities becomes evident when compared with conventional learning. The following is the hypothesis addresses the impact of Earthcomm learning on application skills.

H0 = There is no significant difference between Earthcomm learning and students' spatial thinking ability based on indicators application.

H1 = There are significant differences between Earthcomm learning and students' spatial thinking ability based on indicators application.

The differences in application indicators between two research groups are presented in Table 9.

Table 9

Mann-Whitney U Test Results in Application Indicator

	Application
Mann-Whitney U	251.000
Wilcoxon W	629.000
Z	-2.258
Asymp. Sig. (2-tailed)	.024

According to the data in Table 9, the Mann-Whitney U test results for the application indicator yielded a 2-tailed significance value of 0.024, which is less than 0.050. These results showed that there is a significant difference in the application indicator between the experimental group and the control group.

This difference is also shown by the posttest results of the experimental group, where their scores surpassed those of the control group. The experimental group, implementing Earthcomm learning, achieved an average score of 83.9, while the control group, employing conventional learning, attained an average score of 65.7 (Figure 4). The results of the Mann-Whitney test presented in Table 9 confirm the acceptance of the H1 hypothesis and the rejection of the H0 hypothesis. This implies that the Earthcomm learning model has an impact on students' spatial application abilities.

The Effect of Earthcomm Learning on Spatial Interaction Ability

The following hypothesis pertains to the impact of Earthcomm learning on spatial interaction skills.

H0 = There is no significant difference between Earthcomm learning and students' spatial thinking ability based on indicators spatial interaction.

H1 = There are significant differences between Earthcomm learning and students' spatial thinking ability based on indicators spatial interaction.

The effect of Earthcomm learning on spatial interaction abilities between the two research groups is presented in Table 10.

Table 10

Mann-Whitney U Test Results in Spatial Interaction Indicators

	Spatial interaction
Mann-Whitney U	116.000
Wilcoxon W	494.000
Z	-4.965
Asymp. Sig. (2-tailed)	.000

According to Table 10, the Mann-Whitney U test yielded a 2-tailed significance value of (0.000 < 0.050) for the spatial interaction indicator. These results showed a significant difference in the application indicator between Earthcomm learning and conventional learning. This difference is further highlighted by higher posttest results in the experimental group compared to the control group. The average score of the experimental group, which underwent Earthcomm learning, was 92.9. In contrast, the average score of the control group that received conventional teaching was 51.9 (Figure 4).

The Mann-Whitney test outcomes presented in Table 10 support acceptance of the H1 hypothesis and the rejection of the H0 hypothesis. This suggests that the Earthcomm learning model indeed influences students' spatial interaction abilities.

The Effect of Earthcomm Learning on Scale Ability

The effect of Earthcomm learning on scale abilities becomes evident when compared to conventional teaching. The subsequent hypothesis concerns the effects of Earthcomm learning on scale skills.

H0 = There is no significant difference between Earthcomm learning and students' spatial thinking ability based on indicators scale.

H1 = There are significant differences between Earthcomm learning and students' spatial thinking ability based on indicators scale.

The differences in scale indicators were examined through the Mann-Whitney U test and are displayed in Table 11.

Table 11

Mann-Whitney Results in Scale Indicator

	Scale
Mann-Whitney U	245.000
Wilcoxon W	623.000
Z	-2.478
Asymp. Sig. (2-tailed)	.013

According to Table 11, the Mann-Whitney U test yielded two-tailed significance value of (0.013 < 0.050) for the Scale indicator. These results showed a significant difference in the application indicator between Earthcomm learning and conventional learning. This difference is further shown by the experimental group's posttest results, which are higher than those of the control group. The average score of the experimental group that applied Earthcomm learning was 80.4, while the average score of the control group that applied conventional learning was 57.4 (Figure 4).

The Mann-Whitney U test results presented in Table 8 support H1 hypothesis and the rejection of the H0 hypothesis. This suggests that the Earthcomm learning model has an impact on students' spatial scale abilities.

The Effect of Earthcomm Learning on Representation Ability

The following hypothesis pertains to the impact of Earthcomm learning on representation skills.

H0 = There is no significant difference between Earthcomm learning and students' spatial thinking ability based on indicators representation.

H1 = There are significant differences between Earthcomm learning and students' spatial thinking ability based on indicators representation.

The effect of Earthcomm learning on representation abilities between two research groups is shown in Table 12.

Table 12

Mann-Whitney U Test Results in Representation Indicator

	Representation
Mann-Whitney U	218.500
Wilcoxon W	596.500
Z	-2.888
Asymp. Sig. (2-tailed)	.004

According to Tabl12, the Mann-Whitney U test yielded a two-tailed significance value of (0.040 < 0.050) for scale indicator. These results showed a significant difference in the application indicator between Earthcomm learning and conventional learning. This difference is also evident in the posttest results of the experimental group, which were higher compared to the control group. The experimental group, which employed Earthcomm learning, achieved an average score of 83.3, while the control group utilizing conventional learning attained an average score of 63.0 (Figure 4). The results of the Mann-Whitney U test presented in Table 8 demonstrated that the H1 hypothesis is accepted and the H0 hypothesis is rejected. This implies that the Earthcomm learning model has an impact on students' spatial representation abilities.

Discussion

Based on the research findings, the application of Earthcomm and conventional learning to spatial thinking skills can be explained through each spatial thinking indicator.

Analysis ability of high school students in Earthcomm learning

As presented in Table 4, variations can be observed in the average scores of students' analytical abilities when employing Earthcomm and conventional learning. Analytical ability was evaluated using the Sharpe-Huynh model of spatial thinking ability test, which explores the relationship among phenomena (Huynh & Sharpe, 2013).

The findings presented in Table 7 showed that the application of Earthcomm learning contributes to an enhancement of analytical skills among high school students. Analytical ability plays a pivotal role in helping students to tackle problems linked to their surrounding phenomena (Prastiyono et al., 2021). Moreover, this skill can enhance their learning achievements, particularly within the realm of geography (Imaniar et al., 2021; Utami & Zain, 2018).

Students who engage in Earthcomm learning exhibit sharper analytical skills compared to those who do not. A heightened capacity for precise analytical observation reflects enhanced reasoning ability, thereby augmenting students' spatial intelligence (Juliasz, 2021; Polat, 2020).

Comprehensive ability of high school students in Earthcomm learning

After analyzing the differences in comprehensive ability among high school students, it is evident that Earthcomm learning has an effect on students' comprehensive ability (Hidayat et al., 2017). The development of high school students' comprehensive abilities is influenced by various essential aspects of the Earthcomm learning stages. At this stage, students have the opportunity to foster and refine their comprehensive skills through practical application in various activities.

Learning abilities such as cognitive, affective and psychomotor abilities can help students to think, improve sensitivity and be active in learning (Amin et al., 2020). The learning stage that supports increasing comprehensive abilities is ‘‘the think about it’’ stage. During this stage, students are engaged in meticulous contemplation while studying various natural phenomena within their school environment (Carpenter & Hoover, 2019). Moreover, in the stage of ‘‘reflecting on the activity’’ and the ‘‘challenge,’’ both students and teachers engage in collaborative reflection to address and assess the results of their field investigations and observations (Prastiyono et al., 2021). This stage provides students with an opportunity to express their thoughts in analyzing the field investigations. Comprehensive abilities are also well trained at the ‘‘digging deeper’’ learning stage (Boonen et al., 2014; Polat, 2020).

During this stage, students try to develop their literacy skills by reviewing various sources information to support the investigation findings derived from the field. Geographic literacy skills can be developed effectively when they are reinforced by experiential learning opportunities (Barnes et al., 2014; Kamil et al., 2020).

Application ability of high school students in Earthcomm learning

Based on the analysis results presented in Table 9, it can be concluded that Earthcomm learning contributes to the enhancement of application abilities among high school students. The application abilities referred is the student’s ability to understand the surrounding school environment and city environment (Purwanto et al., 2021). Furthermore, this entails the students' proficiency in utilizing geospatial tools such as compasses, maps, Google Map applications, and online GPS services available on their phones (Fleming & Mitchell, 2017; Juliasz, 2021).

Students with good application abilities demonstrate competence in accurately pinpointing absolute locations on a map (Duarte, 2021; Guerreiro et al., 2017). Employing various contextual applications can facilitate the cultivation of students' spatial concepts to provide meaning (Juliasz, 2021).

The application ability to identify location and space is supported by Earthcomm learning. Earthcomm learning model incorporates an ‘‘investigation’’ stage, which guides students in conducting investigations by looking for locations on the map and finding actual locations in the field (Prastiyono et al., 2021).

Students can access all the tools and applications provided by the teacher, such as a compass and a village map that featuring the precise location of the school. Additionally, students utilize mobile phones equipped with the Google Maps application and online GPS functionalities. Employing this geospatial technology can improve enhance students' spatial abilities, particularly their application abilities (Amin et al., 2020), including activities like map creation that contribute to refining visual-spatial abilities (Johnson & McNeal, 2021).

Spatial interaction ability of high school students in Earthcomm learning

The data analysis results presented in Table 10 showed that Earthcomm learning can improve the spatial interaction abilities among high school students. The spatial interaction ability in Earthcomm learning is related to spatial phenomena (Huynh & Sharpe, 2013; Park, 2001). The phenomena explored by students encompass both physical and social aspects within the school environment, the State of Indonesia territory, and the Asian region. This ability can be realized through the implementation of Earthcomm learning within the ‘‘digging deeper’’ and ‘‘check your understand’’ stages (Hidayat et al., 2017). During these stages, students engage in thorough exploration of physical or social phenomena, subsequently integrating their findings into reports and everyday tasks. Within Earthcomm learning, students are encouraged to establish connections between various physical and social phenomena within a given area. Learning that immerses students in real contexts has the potential to foster collaboration, social values and students' understanding of spatial and environmental phenomena (Kaplan & Berman, 2010; Zelenski et al., 2015). The ability to think spatially is naturally owned by students, but this ability needs to be developed by teaching the surrounding environment problems (Nhlumayo, & Mofokeng, 2023; Prastiyono et al., 2021).

Scale ability of high school students in learning Earthcomm

The data analysis results presented in Table 11 show that Earthcomm learning has an influence in increasing the scale ability of high school students compared to conventional learning. The scale ability in Earthcomm learning is a mathematical ability to understand the comparison of scale, area, region and mapping (de Queiroz, 2021).

This scale ability can be significantly improved through students' active involvement in field investigations, practical application of knowledge, and conduct additional investigations using maps as clues (Duarte, 2021; Polat, 2020). This is in contrast to conventional learning, which primarily relies on small-scale maps within the classroom. Scale ability, which relies on mathematics and calculating skills, can be developed more effectively when integrated with 2- and 3-dimensional visualization skills in learning process (Uttal & Cohen, 2012). Incorporating large-scale maps functions in training students' mental maps (Mohan et al., 2015). Students can make comparisons between the phenomena shown on the map and the actual appearance in the field (3-dimensional visuals).

Representation ability of high school students in learning Earthcomm

The data analysis results presented in Table 12 showed that Earthcomm learning plays a role in increasing the high school students' representation abilities. The representation ability is student's thinking ability to represent ideas to solve problems of spatial phenomena. Representation can be interpreted as a meaningful disclosure of something or a phenomenon (Septia et al., 2019).

Within the framework of Earthcomm learning, the stages of ‘‘think about it’’, ‘‘investigation’’, ‘‘reflecting on the activity’’, and ‘‘challenge’’ collectively help students in cultivating ideas to offer solutions for problems and challenges encountered during the initial learning meeting (Boonen et al., 2014). The research outcomes are further corroborated by a prior study that indicated a noteworthy positive correlation between representation ability and problem-solving proficiency (Boonen et al., 2014). Moreover, using representation tools in maps on textbooks (Duarte, 2021) and using Google Earth satellite images (Purwanto et al., 2021) can develop students' spatial thinking. Other studies also stated that improving spatial representation abilities is particularly crucial for students with lower spatial skills (Yao et al., 2019). Using web GIS in learning geography can help students in representing spatial data (Mkhize, 2023a; 2023b; Santoso et al., 2021). Repeated practice is needed to improve this representation ability (Aliman et al., 2019; Barnes et al., 2014; Yao et al., 2019).The results of this study hold considerable implications for the learning strategies. The Earthcomm learning method not only facilitates the development of students' spatial thinking abilities, but also yields a positive impact on the improvement of the six measured indicators. Moreover, the utilization of Earthcomm learning demonstrates the possibility of further implementation in the field of geography education across different countries. The research findings demonstrate the novelty of this study. Specifically, the study has made a noteworthy theoretical contribution by systematically measuring six indicators of spatial thinking, which builds upon previous research in the field. This study provides empirical evidence supporting the effectiveness of Earthcomm learning as an effective method for improving students' spatial thinking abilities.

Conclusion

Based on the results and discussion, it can be concluded that the senior high school students' spatial thinking abilities across the six indicators (analysis, comprehensive, application, spatial interaction, scale and representation) demonstrated an advancement from low-moderate level to moderate-high level. Earthcomm learning significantly influences the enhancement of spatial thinking skills among high school students across indicators such as analysis, representation, application, scale, spatial interaction, and comprehension. Through the utilization of Earthcomm learning, students are provided the opportunity to develop spatial thinking abilities in the indicators of analysis, comprehension, application, spatial interaction, scale, and representation.

Recommendations

Based on the conclusion, the research suggests all geography teachers assess students' spatial thinking skills. It is recommended that geography teachers implement the Earthcomm learning model due to its proven effectiveness in enhancing the spatial thinking skills of high school students. Furthermore, the incorporation of geospatial technology into the open-source applications and software should be integrated into the learning process. This research can be further expanded through the incorporation of STEM, TPACK, and SETS approaches, alongside various other learning models. Future studies could also explore additional factors, such as gender and the learning environment, in relation to spatial thinking.

Study Limitations

This research focuses solely on spatial thinking ability using six indicators. However, this study does not delve into other factors beyond classroom environment that can impact spatial abilities. Additionally, the study spanned a duration of three months for both the experimental and control groups.

This research is still limited to Padang city, Indonesia, necessitating broader implementation across schools in major urban areas or remote villages. The findings of this study suggest that for optimal Earthcomm learning effectiveness, allocating more time specifically for outdoor learning activities comes highly recommended.

Future researchers are advised to investigate various cognitive, attitude, and skill variables within the realm of geography, assessing their influence on the spatial thinking abilities of high school students.

Acknowledgments

This research received funding through a PNBP grant from the Universitas Negeri Malang. The Department of Geography, Faculty of Social Sciences, State University of Malang provided support to facilitate the publication of this article.

Gratitude is extended to the West Sumatra Provincial Education Office and all members of SMAN 15 Padang. This research maintains no conflicts of interest concerning individuals, groups, or institutions. The authors have affirmed that this manuscript has not been published elsewhere and is presently being considered for publication elsewhere. Furthermore, the copyright of this manuscript will be assigned to The Journal of Social Studies Education Research, and it is intended to be published exclusively in JSSER.

References

Alajmi M.M. (2021). The Effect of Blended Learning on the Degree of Students' Acquisition of Geography Skills for the Eleventh Level at the Secondary Stage in Kuwait. *Journal of Social Studies Education Research, 12* (4), 93 - 120. https://jsser.org/index.php/jsser/article/view/3625/532

Aliman, M., Budijanto, Sumarmi, Astina, I. K., Putri, R. E., & Arif, M. (2019). The effect of Earthcomm learning model and spatial thinking ability on geography learning outcomes. *Journal of Baltic Science Education*, *18*(3), 323–334. https://doi.org/10.33225/jbse/19.18.323

Aliman, M., Ulfi, T., Lukman, S., & Muhammad, H. H. (2019). Konstruksi tes kemampuan berpikir spasial model sharpe-huynh.*Jurnal Georafflesia*, *4*(1), 1–11. https://doi.org/10.32663/georaf.v4i1.738

Amin, S., Sumarmi, S., Bachri, S., Susilo, S., & Bashith, A. (2020). The effect of problem-based hybrid learning (PBHL) models on spatial thinking ability and geography learning outcomes. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(19), 83–94.

Barnes, M. A., Raghubar, K. P., Faulkner, H., & Denton, C. A. (2014). The construction of visual–spatial situation models in children's reading and their relation to reading comprehension. *Journal of Experimental Child Psychology*, *119*, 101–111. https://doi.org/10.1016/j.jecp.2013.10.011

Bednarz, S. (2015). Geographic thinking. *The power of geographical thinking*, 30.

Bond, T. G. (2005). Piaget and the Pendulum. In M. R. Matthews, C. F. Gauld, & A. Stinner (Eds.), *The pendulum: Scientific, historical, philosophical and educational perspectives* (pp. 303–313). Springer Netherlands. https://doi.org/10.1007/1-4020-3526-8_20

Boonen, A. J. H., van Wesel, F., Jolles, J., & van der Schoot, M. (2014). The role of visual representation type, spatial ability, and reading comprehension in word problem solving: An item-level analysis in elementary school children. *International Journal of Educational Research*, *68*, 15–26. https://doi.org/10.1016/j.ijer.2014.08.001

Carpenter, M., & Hoover, M. (2019). What is EarthComm, second edition? [Html]. *EarthComm, Second Edition*. http://www.agiweb.org/education/earthcomm2/about.html

Cortés Loyola, C., Adlerstein Grimberg, C., & Bravo Colomer, Ú. (2020). Early childhood teachers making multiliterate learning environments: The emergence of a spatial design thinking process. *Thinking Skills and Creativity*, *36*, 100655. https://doi.org/10.1016/j.tsc.2020.100655

de Queiroz, A. P. (2021). Spatial thinking: A bibliometric analysis (1970–2019). In S. M. Vanzella Castellar, M. Garrido-Pereira, & N. Moreno Lache (Eds.), *Geographical Reasoning and Learning: Perspectives on Curriculum and Cartography from South America* (pp. 111–122). Springer International Publishing. https://doi.org/10.1007/978-3-030-79847-5_7

Duarte, R. G. (2021). Geography Textbooks in Brazil and the development of spatial thinking in school students using maps and images. In S. M. Vanzella Castellar, M. Garrido-Pereira, & N. Moreno Lache (Eds.), *Geographical Reasoning and Learning: Perspectives on*

Curriculum and Cartography from South America (pp. 247–267). Springer International Publishing. https://doi.org/10.1007/978-3-030-79847-5_14

Fleming, J., & Mitchell, J. (2017). Effects of giant traveling map use on student spatial thinking. *The Geographical Bulletin*, *58*, 67–77.

Flynn, K. C. (2018). Improving spatial thinking through experiential-based learning across international higher education settings. *International Journal of Geospatial and Environmental Research*, *5*(3), 19.

Gold, A. U., Pendergast, P. M., Ormand, C. J., Budd, D. A., & Mueller, K. J. (2018). Improving spatial thinking skills among undergraduate geology students through short online training exercises. *International Journal of Science Education*, *40*(18), 2205–2225. https://doi.org/10.1080/09500693.2018.1525621

Guerreiro, J., Ahmetovic, D., Kitani, K. M., & Asakawa, C. (2017). Virtual navigation for blind people: Building sequential representations of the real-world. *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility*, 280–289.

Hammar, R. K. R., Samangun, C., Malik, Y., & Luturmas, A. (2021). Spatial planning for indigenous law communities to solve social conflict resolution in West Papua Indonesia. *Journal of Social Studies Education Research*, *12*(4), Article 4.

Hidayat, A., Sarwono, & Yusup, Y. (2017). Earthcomm- based multimedia learning of geography in improving learning motivation and spatial ability of the high school students. *Proceedings of The International Conference on Teaching Training and Education 2017 (ICTTE 2017)*. Teacher training and education: Opportunity and challenges in fostering quality learning in open knowledge, Universitas Sebelas Maret, Surakarta, Central Java, Indonesia. https://doi.org/10.2991/ictte-17.2017.29

Huynh, N. T., & Sharpe, B. (2013). An assessment instrument to measure geospatial thinking expertise. *Journal of Geography*, *112*(1), 3–17. https://doi.org/10.1080/00221341.2012.682227

Imaniar, N., Karyanto, P., & Yusup, Y. (2021). *Spatial thinking profile for 2017 surakarta senior high school*. *683*(1), 012036. https://doi.org/10.1088/1755-1315/683/1/012036

Jo, I., Bednarz, S., & Metoyer, S. (2010). Selecting and designing questions to facilitate spatial thinking. *The Geography Teacher*, *7*(2), 49–55. https://doi.org/10.1080/19338341.2010.510779

Johnson, E. T., & McNeal, K. S. (2021). Student perspectives of the spatial thinking components embedded in a topographic map activity using an augmented-reality sandbox. *Journal of Geoscience Education*, *0*(0), 1–12. https://doi.org/10.1080/10899995.2021.1969862

Juliasz, P. C. S. (2021). The role of language in the construction of spatial thinking in early childhood education. In S. M. Vanzella Castellar, M. Garrido-Pereira, & N. Moreno Lache (Eds.), *Geographical Reasoning and Learning: Perspectives on Curriculum and Cartography from South America* (pp. 227–246). Springer International Publishing. https://doi.org/10.1007/978-3-030-79847-5_13

Kamil, P. A., Utaya, S., Sumarmi, & Utomo, D. H. (2020). Improving disaster knowledge within high school students through geographic literacy. *International Journal of Disaster Risk Reduction*, *43*, 101411. https://doi.org/10.1016/j.ijdrr.2019.101411

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspectives on Psychological Science*, *5*(1), 43–57. https://doi.org/10.1177/1745691609356784

Kim, M., & Bednarz, R. (2013). Development of critical spatial thinking through GIS learning. *Journal of Geography in Higher Education*, *37*(3), 350–366. https://doi.org/10.1080/03098265.2013.769091

Mc Leod, S. (2018). *Edward Thorndike: The Law of Effect*. https://www.simplypsychology.org/simplypsychology.org-Edward.pdf

Metoyer, S., & Bednarz, R. (2017). Spatial thinking assists geographic thinking: evidence from a study exploring the effects of geospatial technology. *Journal of Geography*, *116*(1), 20–33. https://doi.org/10.1080/00221341.2016.1175495

Mkhize, T. F. (2023a). Experiences of the geography subject advisors in the implementation of geographic information systems in KwaZulu-Natal Province. *Research in Social Sciences and Technology*, *8*(1), Article 1. https://doi.org/10.46303/ressat.2023.5

Mkhize, T. (2023b). Teachers’ Perceptions of Paper-Based GIS Implementation in The Rural Learning Ecology. *Journal of Curriculum Studies Research, 5*(2), 118-135. https://doi.org/10.46303/jcsr.2023.20

Mohan, L., Mohan, A., & Uttal, D. (2015). *Research on thinking and learning with maps and geospatial technologies*. http://groups.psych.northwestern.edu/uttal/documents/Mohanetal2015.pdf

Nhlumayo, B., & Mofokeng, M. (2023). Managing Change in the Teaching and Learning of Geography in South African FET Classrooms. *Journal of Curriculum Studies Research*, 5(3), 16-28. https://doi.org/10.46303/jcsr.2023.28

Ningrum, M. V. R., & Kholiq, E. (2018). The influence of earth science community learning model (EARTHCOMM) to learning outcomes of geography. *Proceedings of the 2017 International Conference on Education and Technology (2017 ICEduTech)*, *144*, 48–50. https://doi.org/10.2991/icedutech-17.2018.8

Park. (2001). *A study of earth system science in the community (Earthcomm) in terms of its Congruency with the visions in the national science education standards and its effectiveness student learning* [Dissertations]. The University of Iowa.

Pilato, J., Peterson, E. G., & Anderson, A. (2023). Spatial thinking activities in PK-12 classrooms: Predictors of teachers' activity use and a framework for classifying activity types. *Teaching and Teacher Education*, *132*, 104226. https://doi.org/10.1016/j.tate.2023.104226

Polat, S. (2020). Multidimensional Analysis of the Teaching Process of the Critical Thinking Skills. *Research in Social Sciences and Technology*, 5(2), 134-157. https://doi.org/10.46303/ressat.05.02.8

Prastiyono, H., Utaya, S., Sumarmi, S., Astina, I. K., Amin, S., & Aliman, M. (2021). Development of e-learning, mobile apps, character building, and outdoor study (EMCO learning model) to improve geography outcomes in the 21st century. *International Journal of Interactive Mobile Technologies (IJIM)*, *15*(07), Article 07.

Purwanto, P., Utaya, S., Handoyo, B., Bachri, S., Yulistiya, D., & Amin, S. (2021). The spatial thinking ability students on the character of urban and rural environments in solving population problems. *Review of International Geographical Education Online*, *11*(3), Article 3. https://doi.org/10.33403/rigeo.877708

Ridha, S., Utaya, S., Bachri, S., & Handoyo, B. (2019). Students' geographic skills in Indonesia: Evaluating learning material questions about GIS using taxonomy of spatial thinking. *Journal of Social Studies Education Research*, *10*(4), https://jsser.org/index.php/jsser/article/view/360/417

Romadlon, R. W., Yusuf, Y., & Sarwono. (2021). *Effect of learning project model-based learning on GIS spatial thinking skills students*. *683*(1), 012045. https://doi.org/10.1088/1755-1315/683/1/012045

Santoso, A. B., Juhadi, Wijayanto, P. A., Setiawan, S., Sa'adah, N., Masruroh, N., & Rahmah, N. A. (2021). *The utilization of technology-based Webgis as an effort to establish the spatial thinking ability of geographic students in high school*. 21–25. https://doi.org/10.2991/assehr.k.210918.005

Septia, E., Marni, S., & Armet, A. (2019). Representasi Nilai Religi dan Kepengarangan Puisi-Puisi Karya Taufik Ismail [Representation of religious values and authorship of Taufik Ismail's Poems]. *Poetika: Jurnal Ilmu Sastra*, *7*(1), Article 1. https://doi.org/10.22146/poetika.v7i1.43493

Sudatha, G. W., Degeng, N. S., & Kamdi, W. (2018). The effect of visualization type and student spatial abilities on learning achievement. *Journal of Baltic Science Education*, *17*(4), 551–563.

Utami, W., & Zain, I. (2018). Geography literation to improve spatial intelligence of high school student. *Journal of Physics: Conference Series*, *953*, 012173. https://doi.org/10.1088/1742-6596/953/1/012173

Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education: When, why, and how? In *The psychology of learning and motivation, Vol. 57* (pp. 147–181). Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-394293-7.00004-2

Wijayanto, B., Sumarmi, S., Utomo, D. H., Handoyo, B., & Aliman, M. (2023). Development of e-module based on geospatial technology to improve TPACK competencies of geography pre-service teacher: A needs analysis review. *TEM Journal*, *12*(2), 1190–1200. https://doi.org/10.18421/TEM122-65

Yao, C. J., Chow, J., Choi, W. W. S., & Mattheos, N. (2019). Measuring the impact of simulation practice on the spatial representation ability of dentists by means of Impacted Mandibular Third Molar (IMTM) Surgery on 3D printed models. *European Journal of Dental Education*, *23*(3), 332–343. https://doi.org/10.1111/eje.12434

Zelenski, J. M., Dopko, R. L., & Capaldi, C. A. (2015). Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behavior. *Journal of Environmental Psychology*, *42*, 24–31. https://doi.org/10.1016/j.jenvp.2015.01.005

Zid M. & Casmana A.R. (2021). A learning model for teaching “population geography” course in higher education through case study of international women's migration. *Journal of Social Studies Education Research, 12* (3), 120 – 143. https://jsser.org/index.php/jsser/article/view/3251/516