

## Students' Geographic Skills in Indonesia: Evaluating GIS Learning Material Questions Using Taxonomy of Spatial Thinking

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### Abstract

Geographic skills area major competency that must be developed through spatial thinking. This paper describes whether learning material questions about Geographic Information System (GIS) in geography textbooks contains components of spatial thinking: concepts of space, use of representation tools, and reasoning processes. This study uses a descriptive qualitative approach with content analysis design. We conducted the evaluation of learning material questions about GIS on four geography textbooks of senior high schools in Indonesia by coding using taxonomy of spatial thinking. The 92 questions evaluated in this study contained multiple choice and essay practice questions. We identified questions by the following steps: 1) classifying concepts of space questions into non-spatial, spatial primitives, simple spatial, complex spatial; 2) determining the nature of tools of representation in the questions—use and non-use; 3) classifying processes of reasoning from each question into input, processing, and output. The results showed that the majority of GIS learning material questions are not based on spatial thinking. Seventy-one percent of questions are non-spatial, 73 percent of questions did not use maps to represent spatial thinking, and 67 percent of questions are low-level reasoning process (input). These findings indicate that GIS learning material questions in geography textbooks do not include the complete spatial thinking component. As a result, the lack of a complete spatial thinking component in GIS learning material questions in geography textbooks results in less developed geography competency among students. Learning material questions should contain the components of spatial thinking at a high level, such as using complex spatial on concepts of space, using tools for representation, and using output for reasoning processes. Therefore, for geographic textbooks, the National Education Standards Agency must develop standardized questions focused on spatial concepts to represent high-level spatial thinking.

**Key words:** *Geographic skills, Evaluating, GIS Learning Material Question, Taxonomy of Spatial Thinking, Indonesia*

### Introduction

To improve students' geographic skills, it is critical that spatial thinking is integrated into student practice questions in Geographic Information System (GIS) learning materials. Spatial thinking is an essential element in geography education (Heffron & Downs, 2012) because it helps students to represent, analyze, plan an area, and connect between objects and humans (Heffron, 2012). Besides, it is important for students to improve their understanding

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of location, distribution, interrelation of geosphere phenomena, and the use of geospatial technologies such as GIS, remote sensing, and GPS (global positioning systems) (Gersmehl, 2008). Students generate hypotheses by asking “what if” questions involving spatial thinking to solve spatial problems and to improve their ability to interpret maps correctly (Chu et al., 2016). The form of the question becomes an analytical tool that leads to a general hypothesis about spatial phenomena. This is why the components of spatial thinking need to be included in GIS learning material questions.

GIS can increase spatial thinking and geographic skills (Chun, 2010) and influences spatial thinking; once students learn GIS, their spatial thinking skills improve (Lee & Bednarz, 2009; Madsen & Rump, 2012). Learning GIS can improve students' understanding of location, scale, representation, and distance (Sinton, 2015). GIS becomes a principle tool in learning geography to describe objects on the surface of the earth (DeMers, 2016). Learning GIS is important in learning geography to improve spatial thinking and geographic skills. Unfortunately, in Indonesia there is no study that focuses on this issue. However, the latest National Curriculum expects student improvement in geographic skills, especially in map creation.

Previous research has attempted to evaluate geography textbook questions in general; past research has not focused on a particular topic. For example, a study conducted by Scholz et al., (2014) in university geography textbooks in the USA concluded that the majority of questions did not use representation tools and the concepts of space. For this reason, this study focuses on evaluating GIS learning material questions contained in senior high school geography textbooks in Indonesia. The findings of this study will be used to design questions with spatial thinking.

Questions that contain spatial thinking must include three components: spatial concepts, representation, and reasoning (Wakabayashi & Ishikawa, 2011; Moore-Russo, Viglietti, Chiu, & Bateman, 2013; Metoyer & Bednarz, 2017). Other experts propose that there are three components of spatial thinking in geography textbook questions: concepts of space, use of representation tools, and reasoning processes (National Research Council, 2006; Jo & Bednarz, 2011).

Components of spatial thinking must be integrated into GIS material questions (Bodzin, 2011; Jo, Klein, Bednarz, & Bednarz, 2012). Questions with spatial thinking must be implemented in GIS learning materials to help students obtain geographic skills. Learning GIS helps students think spatially; this is evident from the increase of result and relationship between activities and GIS learning experiences of spatial thinking skills (Lee & Bednarz,

2012). Currently, learning material in Indonesia does not integrate components of spatial thinking to improve spatial thinking skills. Therefore, it is necessary to evaluate GIS learning material questions in senior high school geography textbooks against the current Indonesia National Curriculum standards.

The geography education curriculum of senior high school in Indonesia refers to the competency standards of the current National Curriculum, which expects an increase in geographic skills. For example, students are expected to be able to make a map of disaster potential in an area and explain disaster mitigation strategies based on the map. To achieve this competency standard, students need the geographic skill to create maps through GIS. The instruction for this competency needs to be developed in schools (Alhosani & Yagoub, 2015). In other words, this competency emphasizes mastering GIS to create maps. Students will be expected to use geospatial technology to make maps. To achieve geographic skills, students need spatial thinking assignments or questions that involve the use of GIS in creating maps.

This leads to the question: do GIS learning material questions in current geography textbooks contain components of spatial thinking to improve students' geographic skills? To answer this question, researchers should evaluate instructional material questions about GIS by finding out whether the questions involve components of spatial thinking or not (Jennings, 2006; Yasar & Seremet, 2007), so that, the weaknesses of learning material questions about GIS can be detected and corrected (Lee & Catling, 2017).

Evaluation of GIS learning material questions based on spatial thinking in geography textbooks is important to because teachers in Indonesia depend heavily on textbooks as they teach geography in senior high school (Purwanto, Fatchan, Purwanto, & Soekamto, 2015). This becomes a problem because teachers use textbooks without first evaluating the questions (Bednarz, Stoltman, & Lee, 2004; Purwanto, 2013; Shin, Milson, & Smith, 2016). As a result, the expected learning goals cannot be achieved (Wang & Chen, 2013). It is necessary to evaluate GIS learning material questions geography textbooks using taxonomy of spatial thinking to find out whether learning material questions about GIS contain components of spatial thinking or not (Zhang & Foskett, 2003; Jennings, 2006).

### **Literature Review**

Spatial thinking combines cognitive skills (National Research Council, 2006). It is defined as knowledge, skills, and thinking habits to use the concepts of space such as distance, orientation, distribution, and association; representational tools such as map, graph, and diagram; and reasoning processes such as cognitive strategy to facilitate problem solving and

decision making to structure problems, find answers, and express solutions to problems (National Research Council, 2006; Collins, 2018). Metoyer & Bednarz (2017) expressed similar views that spatial thinking builds cognitive skills through the combined concepts of space, the use of representational tools, and reasoning processes. The keys to spatial thinking consist of three components: concepts of space, use of representation tools, and reasoning processes (Lee & Bednarz, 2012).

These three components of spatial thinking can be used in geography learning, especially in learning GIS. Learning GIS influences spatial thinking skills, as evidenced by improved test scores. Learning GIS can help students think spatially (Lee & Bednarz, 2009). Another opinion suggests that spatial thinking is the ability to visualize and solve problems spatially (Nielsen, Oberle, & Sugumaran, 2011; Turenliyazova, 2019). These three components of spatial thinking are explained as follows.

### ***Concepts of Space***

Concepts of space help us understand location, distance, pattern, affordability, morphology, association, spatial relationship, and the relationship of a geosphere phenomenon (Golledge, 2002; Gersmehl & Gersmehl, 2007). Concepts of space are divided into four subcategories: non-spatial, spatial primitives, simple spatial, and complex spatial (Jo & Bednarz, 2009; Scholz et al., 2014). These four subcategories are represented by questions.

Questions categorized as non-spatial are questions that do not contain the components of spatial thinking (Scholz et al., 2014). Example question: How many people come from Pidie District in Takengon City, Central Aceh-Indonesia?

Spatial primitives are concepts of space at a low level that use the concepts of location, place-specific, identity, and magnitude in questions (Golledge, 1995). Example question: What province is located between Central Java and Bali in Indonesia? This question is identified as a specific place between Central Java and Bali.

Simple spatial is a concept of space at a higher level than spatial primitives based on concepts and distribution, including distance, direction, connection and linkage, movement, transition, boundary, region, shape, reference frame, arrangement, adjacency, and enclosure (Golledge, 1995; Scholz et al., 2014). Example question: In what climate areas can the rainforest be found? This question is identified as the distribution of forests in the world based on latitude.

Complex spatial is the highest spatial concept based on spatial distribution, including distribution, pattern, dispersion and clustering, density, diffusion, dominance, hierarchy and

network, spatial association, overlay, layer, gradient, profile, relief, scale, map projection, and buffer (Golledge, 1995, 2002; Scholz et al., 2014). Example question: Where is the best place in Banda Aceh-Indonesia to establish coastal disaster prevention forest by considering the distribution of population and land available on the city planning map? This question is identified as a concept of distribution and spatial association based on available data.

### ***Using Tools of Representation***

The second component of spatial thinking is using tools to represent information. The tools are map, diagram, graph, chart, photo, and answering questions (Jo & Bednarz, 2011; Scholz et al., 2014). This component is divided into two subcategories: use and non-use. Use involves questions that require the use of representation tools to answer those questions. Example question: Based on the satellite image of Palu City after the earthquake and tsunami (September 28, 2018), which caused damage of infrastructure and socio-economy, to build Palu City, what geographical approach is used? Non-use is questions that do not use representation tools to answer questions. These are not classified into spatial thinking questions (Scholz et al., 2014). Example question: Who is the inventor of planetesimal theory? This question does not require map, graphic, or other representations to answer questions.

### ***Processes of Reasoning***

The third component is processes of reasoning, which are cognitive skills that require complex reasoning (Jo & Bednarz, 2009). For example, reasoning could be activity that involves interpreting information on a map and using that information.

Interpretation is carried out by mentioning, explaining, and analyzing objects on a map. Processes of reasoning are divided into three subcategories: input, processing, and output (Scholz et al., 2014). Input is the receipt of information at low level, including name, definition, list, identify, recognize, recite, recall, observe, describe, select, complete, count, and match (Lee & Bednarz, 2012). Example question: Mention five of the most populous cities on Java-Indonesia. This question asks students to name five of the most densely populated cities in Java and it is evaluated as an input question in taxonomy.

Processing is a higher level reasoning process; it is the act of analyzing information received, including explain, analyze, state causality, compare, contrast, distinguish, classify, categorize organize, summarize, synthesize, infer, make analogies, exemplify, experiment, and sequence (Jo, Bednarz, & Metoyer, 2010; Scholz et al., 2014). Example question: Explain the factors that cause population density in a city and explain the relationship between crime rate

and densely populated city. This question asks students to analyze population density factors and explain the relationship between population density and crime.

Output is the highest level of reasoning process; it uses analysis of information received to evaluate, judge, predict, forecast, hypothesize, speculate, plan, create, design, invent, imagine, generalize, build a model, apply a principle (Jo & Bednarz, 2009). Example question: Based on the rainfall data displayed on the map in Batu City, Indonesia, which plantations are suitable to be developed in the region? This question asks students to predict and evaluate as output.

Taxonomy of spatial thinking used to evaluate GIS learning material questions is explained in Figure 1.

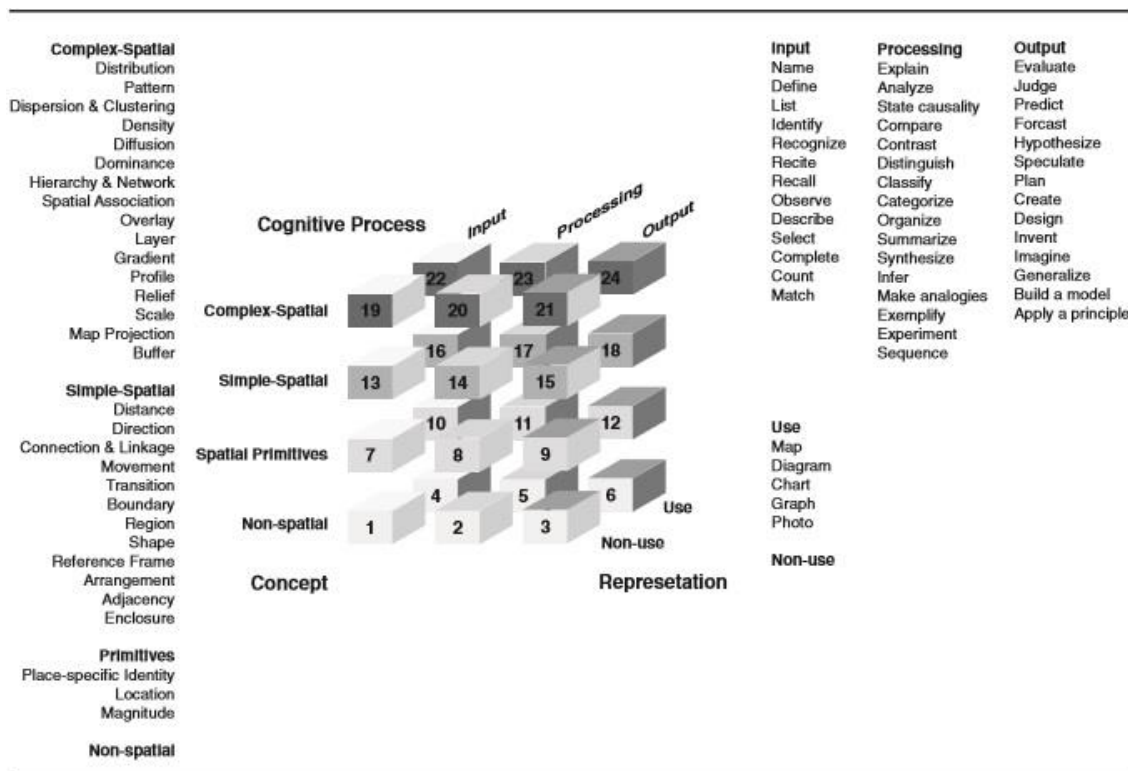


Figure 1. Taxonomy of Spatial Thinking for Evaluating GIS Learning Material Questions (Adapted from Jo & Bednarz, 2009)

## Methods

### Research Design

This study used a descriptive qualitative approach conducted with content analysis design. We used this design to analyze geography textbooks. Content analysis is a method in which content is classified by certain coding scheme (Krippendorff, 2004; Jo, 2007).

### Sources of Data

The data source in this study were senior high school geography textbooks. This study evaluated GIS learning material questions from four senior high school geography textbooks. Those four books were: 1) Textbook A: *Buku Siswa Geografi untuk SMA/MA Kelas X Kelompok Peminatan Ilmu-Ilmu Sosial* (Hermanto, 2016); 2) Textbook B: *Geografi Untuk SMA/MA Kelas X Kelompok Peminatan Ilmu Pengetahuan Sosial* (Priastomo, 2016); 3) Textbook C: *Buku Siswa Geografi Untuk SMA/MA Kelas XII Kelompok Peminatan Ilmu-Ilmu Sosial* (Hermanto & Firman, 2015); and 4) Textbook D: *Geografi untuk SMA/MA Kelas XII* (Wardiyatmoko, 2014). These four books were selected for evaluation because they are the most widely used as learning resources for Indonesia senior high school students and because the books were standardized by the National Education Standards Agency. We then reviewed the selected textbooks for learning material questions about GIS to be evaluated using taxonomy of spatial thinking. We evaluated 92 questions located in assignment, multiple choice, and essay practice questions. Table 1 shows the number and location of the questions evaluated.

Questions are an important part of geography textbooks (Jo & Bednarz, 2009). One component of the material in geography textbooks is GIS, which consists of narrative texts and a series of questions (Kragler, Walker, & Martin, 2005; Jo & Bednarz, 2009). Many questions measure student knowledge about learning material. The questions are placed in the subchapter and the end of the chapter. Some questions are designed for developing skills such as map reading (Jo & Bednarz, 2009). These questions almost always appear on the margins of a page or in an additional section.

**Table 1**

*Number and Locations of GIS Learning Material Questions*

Questions Location	Learning Material A	Learning Material B	Learning Material C	Learning Material D	Total
Assignment	5 (29,5%)	2 (11%)	11 (38%)	4 (15%)	22 (24%)
Multiplechoice	7 (41%)	5 (26%)	11 (38%)	8 (30%)	31 (34%)
Essay	5 (29,5%)	12 (63%)	7 (24%)	15 (55%)	39 (42%)
Total	17 (100%)	19 (100%)	29 (100%)	27 (100%)	92 (100%)

### Data Collection

We used question coding in the data collection conducted in this study. In this part, we focused on the question evaluation. We evaluated the questions by coding that used taxonomy of spatial thinking. Coding of spatial thinking components consists of three categories:

concepts of space, use of representation tools, and reasoning processes (Jo & Bednarz, 2011). Each category consists of subcategories with taxonomy.

Questions were identified by the following steps: 1) classifying concepts of space questions into non-spatial, spatial primitives, simple spatial, and complex spatial; 2) determining the nature of tools of representation in the questions, use and non-use; and 3) classifying processes of reasoning from each question into input, processing, and output. Each question was checked according to concepts of space, using representation tools and reasoning processes to answer questions. Each question was encoded using the numbers assigned to each subcategory. Coding examples are presented in Table 2.

**Table 2**  
*Example of Coding GIS Learning Material Questions*

Question: ____ Find some attribute and map data related to landslides. Make a map of landslide-prone areas by using overlay method manually to produce the latest map.									
Concepts of space				Tools of representation			Processes of reasoning		
0	1	2	✗	0	✗	1	2	✗	
Complex spatial				Use			Output		

(Adapted from Jo, 2007)

Furthermore, the result of coding as shown in Table 2 was interpreted in each question to be set into one of the components of spatial thinking. Examples of spatial and non-spatial thinking questions are presented in Table 3. A question of spatial thinking is a question that is integrated with three components of spatial thinking (Scholz et al., 2014). A non-spatial question of concepts of space uses non-spatial subcategories and non-use tools of representation.

**Table 3**  
*Examples of Spatial and Non-Spatial Thinking Questions*

Question	Category		
	Concepts of space	Tools of representation	Processes of reasoning
Non-spatial thinking question Question in GIS learning materials - What are kinds of geographic information system software?	Non-spatial	Non-use	Input
Spatial thinking question Question in GIS learning materials - Find some attribute and map data related to landslides. Make a map of landslide-prone areas by using overlay method manually to produce the latest map.	Complex spatial	Use	Output

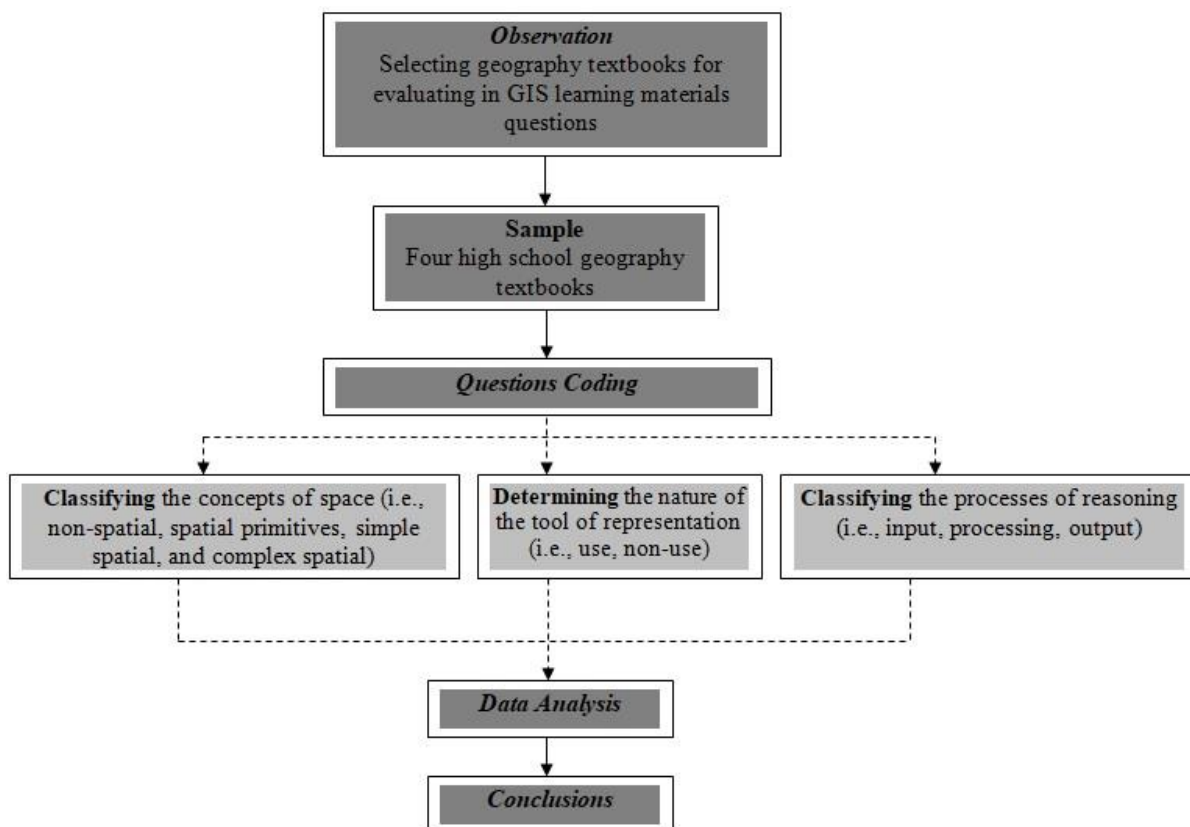


### **Data Analysis**

To analyze our data, we used descriptive statistics presented in the table of relative frequency distribution (Jo, 2007; Mundir, 2013). We then converted the coding results into percentages. After conducting the evaluation, we provided a recommendation based on the evaluation results (Jo et al., 2012; Yang, 2013).

### **Research Procedures**

This research began with observation in schools to gather information about geography textbooks. We conducted the observation in 12 senior high schools in Malang City, East Java Province, Indonesia. Based on our observation, we selected the most commonly used four geographic textbooks for evaluation. These textbooks were also based on the current National Curriculum in Indonesia. In these textbooks, we reviewed GIS learning material questions to be assessed for three components of spatial thinking. The next process was to analyze the data and develop our conclusion. The research framework is described in Figure 2.



**Figure 2.** Evaluating Procedures for GIS Learning Material Questions

### Findings and Discussion

Based on the current Indonesia National Curriculum geographic skills competency standard, the questions of GIS learning materials should be compiled based on the presence of all components of spatial thinking. To achieve the geographic skills standard, it is necessary to develop GIS learning material questions based on spatial thinking. Developed learning material can improve students' understanding of learning material (Gafur, 2012; Ayas, 2015; Aydin, Ozfidan, & Carothers, 2017). Table 4 shows the percentage of components of spatial thinking contained in GIS learning material questions.

**Table 4**

*Percentage of Components of Spatial Thinking in GIS Learning Material Questions*

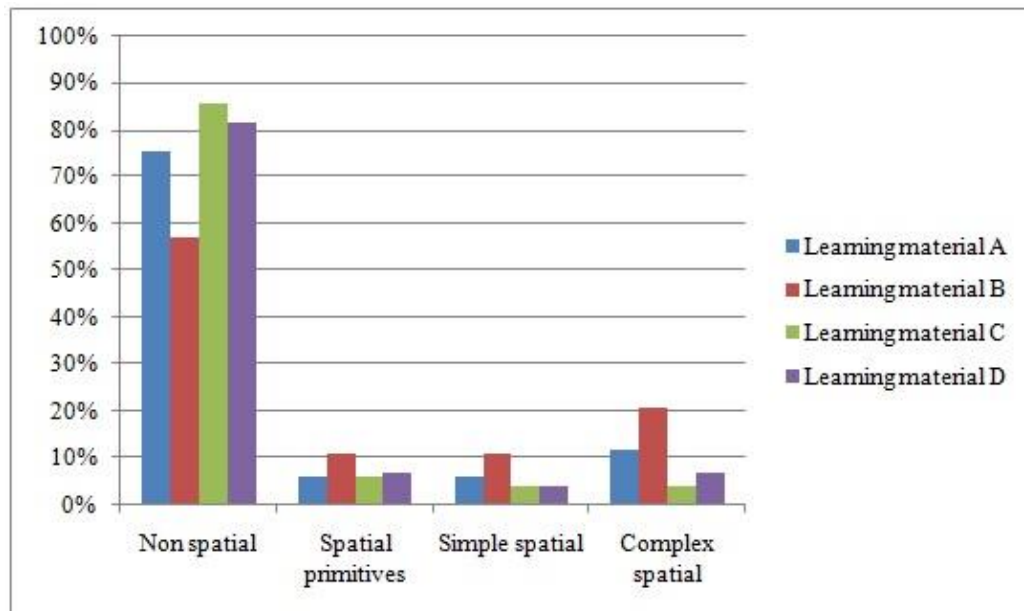
Component of Spatial Thinking		Learning Material A	Learning Material B	Learning Material C	Learning Material D	Total
<b>Number of questions</b>		<b>17</b>	<b>19</b>	<b>29</b>	<b>27</b>	<b>92</b>
Concepts of space	Non-spatial	13 (76%)	11 (57%)	25 (86%)	22 (82%)	71 (77 %)
	Spatial primitives	1 (6 %)	2 (11%)	2 (6%)	2 (7%)	7 (8 %)
	Simple spatial	1 (6%)	2 (11%)	1 (4%)	1 (4%)	5 (5 %)
	Complex spatial	2 (12%)	4 (21%)	1 (4%)	2 (7%)	9 (10 %)
Using tools of representation	Use	3 (18%)	4 (21%)	7 (24%)	5 (18%)	19 (21 %)
	Non-Use	14 (82%)	15 (79%)	22 (76%)	22 (82%)	73 (79 %)
Processes of reasoning	Input	12 (70%)	13 (68%)	22 (76%)	20 (74%)	67 (73 %)
	Processing	2 (12%)	4 (21%)	6 (20%)	5 (19%)	17 (18 %)
	Output	3 (18%)	2 (11%)	1 (4%)	2 (7%)	7 (8 %)

Through our analysis of GIS learning materials in four geography textbooks, we found that the majority of learning material questions about GIS was not developed with spatial thinking components: 71 percent of questions were non-spatial, 73 percent of questions did not use maps to represent spatial thinking, and 67 percent of questions were low-level reasoning process (input). The lack of spatial thinking components causes GIS learning material in geography textbooks to be less effective in the development of geography competency.

Our data analysis reveals that, the questions in current GIS learning materials focus only on low levels of spatial thinking and do not use representation tools and low-level reasoning processes. It can be concluded that the questions are designed without using the taxonomy of spatial thinking. As a result, students' geographic skills cannot be measured. There are three components of spatial thinking that must be contained in GIS learning material questions: concepts of space, use of representation tools, and reasoning processes. Each component has a subcategory to facilitate identifying the level of spatial thinking found in learning material questions about GIS (Scholz et al., 2014). Determination of spatial thinking level in GIS learning material questions is done through compilation of each component of

spatial thinking. The three components of spatial thinking in learning material questions about GIS are explained as follows.

### *Concepts of Space*



**Figure 3.** *Concepts of Space in GIS Learning Material Questions*

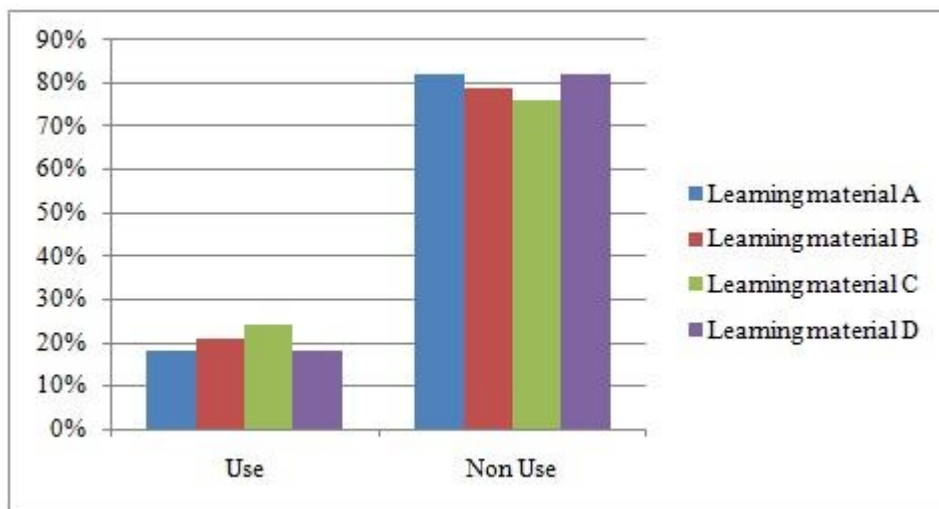
Figure 3 shows that GIS learning material questions are dominated by non-spatial. The questions were designed to be more focused on non-spatial than the other concepts.

Concepts of space consist of questions that contain location, distance, pattern, affordability, morphology, association, spatial linkage, and relationship of geosphere phenomenon (Gersmehl & Gersmehl, 2007; Metoyer & Bednarz, 2017). Concepts of space have some subcategories: non-spatial, spatial primitives, simple spatial, and complex spatial (Golledge, 2002). Non-spatial questions are questions that do not contain spatial elements (Jo & Bednarz, 2011). Example question: How many volcanoes are on the Java Island?

Spatial primitives questions are questions with low-level thinking (Golledge, 1995). Example question: In what province is Mount Bromo located? Simple spatial questions are those with high-level thinking; such questions use the concept of geography. Example question: Why do coffee trees grow in Central Aceh region of Indonesia and do not grow in Banda Aceh city of Indonesia? That question relates to the concept of area deferment. The difference between Central Aceh and Banda Aceh is in altitude, which affects air temperature.

Complex spatial questions are questions with very high-level thinking (Jo & Bednarz, 2011). This level uses the principles of distribution and interrelation to explain geosphere phenomena by overlaying maps or planning maps (Scholz et al., 2014). Example question: Based on the data presented in map, table, graph of distribution of population, availability of raw material, transportation, affordability and morphology, in which areas are the most strategically developed extractive industry locations on the Sumatera Island?

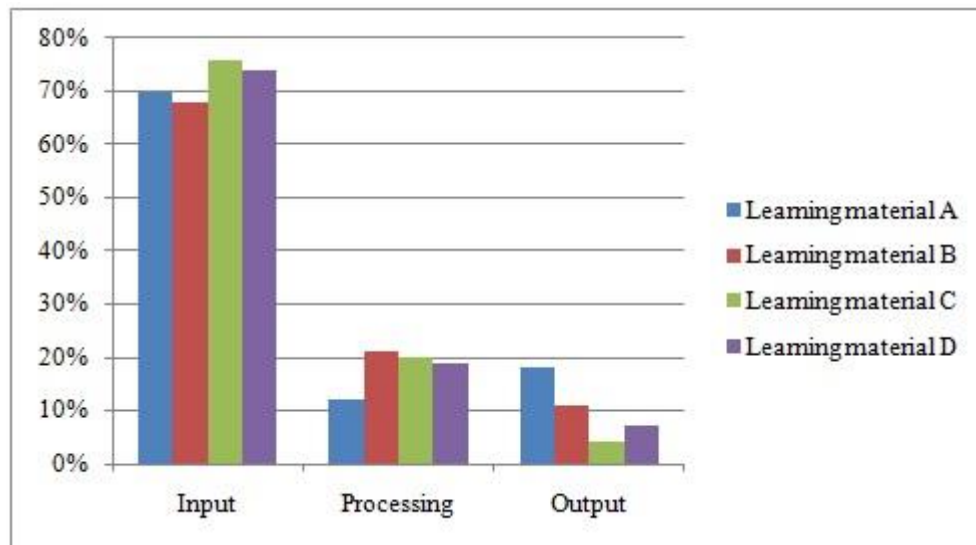
### *Using Tools of Representation*



**Figure 4.** *Using Tools of Representation in GIS Learning Material Questions*

Figure 4 shows that the use of representation tools in GIS learning material questions is dominated by subcategories of non-use. This is due to the absence of the use of representation tools, such as map, chart, graphic, and photo. Using representation tools is the students' task to represent geosphere phenomena using GIS software. This activity is done through laboratory-based learning that requires skills in operating GIS software. As a result, students are expected to be able to produce map, table, sketches, and diagram to explain and identify object on the map and its relation to space (Metoyer & Bednarz, 2017). Thus, using representation tools is the use of map, diagram, chart, graph, and photo (Jo & Bednarz, 2009). Evaluation of GIS learning material questions on this component looks at the presence or absence of representation tools and requires students to use GIS software to create maps. In brief, learning material questions about GIS should focus on higher-level cognitive processes to support the competency level of geographic skills established by the Indonesia National Curriculum.

### *Processes of Reasoning*



**Figure 5.** *Processes of Reasoning in GIS Learning Material Questions*

Figure 5 shows that the reasoning processes in GIS learning material questions are dominated by the subcategory of input. Our analysis shows that the questions were designed to be more focused on low-level reasoning. Processes of reasoning questions are questions that contain elements of reasoning (Jo & Bednarz, 2009). These questions capture the information contained in the map, so that students can use the information to understand the map. Example: a map that shows the distribution of animals and plants in Indonesia. Students perform reasoning by mentioning, explaining, and analyzing objects on the map. The reasoning shows the level of knowledge building in that:

1. input is categorized at low level (Scholz et al., 2014). Example question: Mention three of the most populous cities on Sumatera Island.
2. processing is categorized at high level (Jo & Bednarz, 2009, 2011). Example question: How is the relationship between the crowded population and the market that will be built in the area?
3. output is categorized at a very high level because it uses information to evaluate, assess, predict, design, and create (Scholz et al., 2014). Example question: Based on rainfall data displayed on the map in Lombok Island, what plants are suitable to grow in the region?

## Application of Components of Spatial Thinking in Compiling GIS Learning Material Questions

GIS learning material questions should contain all three components of spatial thinking: concepts of space, use of representation tools, and reasoning processes. Concepts of space has subcategories: non-spatial, spatial primitives, simple spatial, and complex spatial. Use of representation tools has subcategories: use and non-use. Third, reasoning processes has subcategories: input, processing, and output. Each subcategory has a taxonomy used to design GIS learning material questions (Jo et al., 2010). Table 5 shows the taxonomy of spatial thinking integrated into GIS learning material questions.

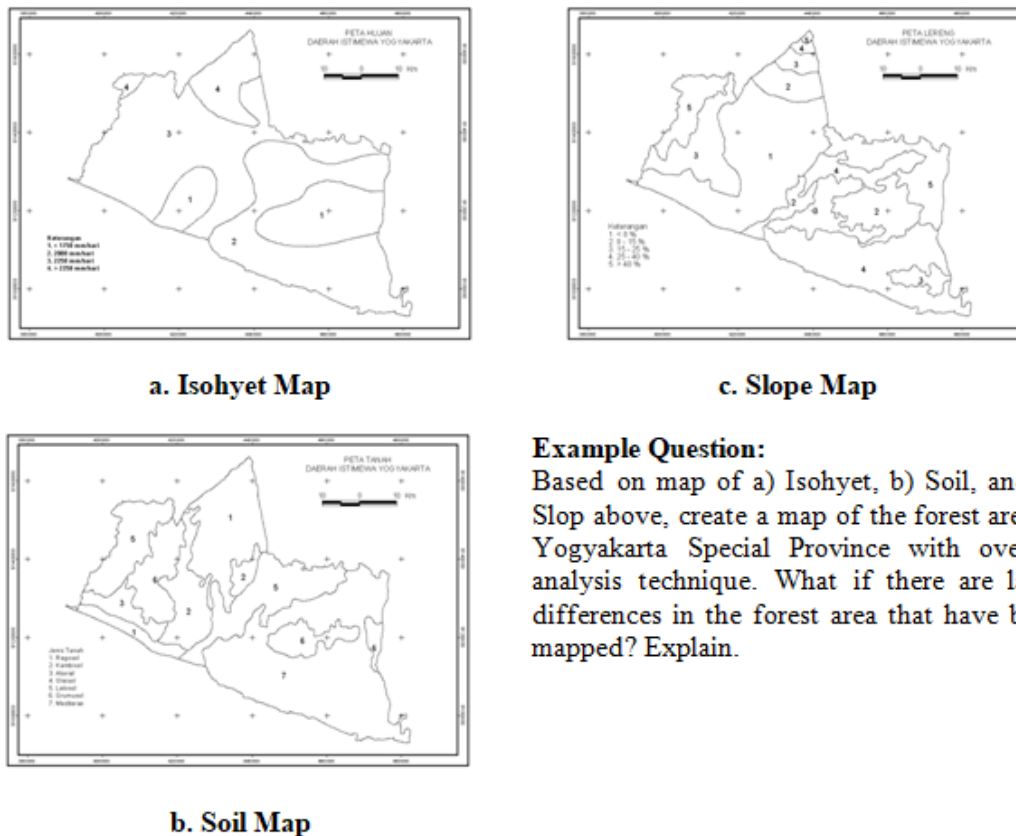
**Table 5**

*Taxonomy of Spatial Thinking Integrated Into GIS Learning Material Questions*

<i>Components of Spatial Thinking</i>		<i>Taxonomy</i>
<i>Category</i>	<i>Subcategory</i>	
Concepts of space	Complex spatial	Overlay
Using tools of representation	Use	Map
Processes of reasoning	Processing	Explain
	Output	Create

Based on Table 5, the GIS learning material questions could be implemented in the form of a thematic map assignment. The map would be made with overlay analysis technique. Students would be assigned to explain the results of analysis by asking the question "What if there are differences in forest distribution based on the overlay result?" Thus, the three components of spatial thinking could be integrated into the question. Examples of questions that could be designed based on Table 5 are shown in Figure 6.

Taxonomy of spatial thinking used in Table 5 is a high level of spatial thinking components. This is seen in the use of the subcategory complex spatial, which includes taxonomy of overlay and using maps as a representation tool. The use of subcategory processing, including taxonomy of explain, is also a high level of component of spatial thinking, in which students are assigned to explain a phenomenon illustrated in maps. In addition, the use subcategory, output using taxonomy of create, is very high-level spatial thinking, in which students are assigned to create maps with GIS.

**Example Question:**

Based on map of a) Isohyet, b) Soil, and c) Slope above, create a map of the forest area in Yogyakarta Special Province with overlay analysis technique. What if there are large differences in the forest area that have been mapped? Explain.

**Figure 6.** Using Taxonomy of Spatial Thinking to Compile GIS Learning Material Questions

The example question above was used in our formative evaluation of learning geography within the evaluation design of a small group trial. The purpose of the evaluation was to find out the effectiveness of the question. The question was tested in two groups of students. In the first group, students were asked to answer the question using a GIS application. In the second group, students were asked to answer the question by overlaying the map manually by using a map depiction on transparent paper. The two groups showed different results. Differences were identified from the maps produced. The first group produced a better map than the second group. The first group created a map in the form of a digital map. The use of a GIS application helped students make decisions more easily in solving a spatial problem. In contrast, the second group needed to interpret the map before deciding upon a solution for a spatial problem. From this, we can see that GIS learning material questions designed using taxonomy of spatial thinking is an effective way to improve students' geographic skills.

This study concludes that spatial thinking in GIS learning material questions in senior high school geography textbooks has not been used effectively. The deficiencies we found in GIS learning materials become an obstacle for students to learn GIS. Students cannot master the concept of GIS without knowing about the benefits of GIS and how to use it. Learning GIS

can improve spatial thinking because GIS affects spatial thinking (Chun, 2010). The lack of effective learning materials in textbooks will hamper Indonesian students from meeting National Curriculum competency standards. The GIS learning material should be of good quality and be easily understood by students. Deficiencies in the learning material result in low numbers of students comprehending GIS learning material (Bearman, Jones, André, Cachinho, & DeMers, 2016). GIS learning material contained in high school geography textbooks does not meet current National Curriculum standards, which require that students should be able to create maps with GIS. The questions should be based on predetermined curriculum standards (Chen & Wang, 2015).

Each question in GIS learning material has three components of spatial thinking. It functions to improve students' ability in spatial thinking (Lubienski & Dougherty, 2009). Spatial thinking is the basis of the latest geographic skills that must be developed in school (Jo et al., 2010). Learning GIS is an essential principle for understanding geosphere phenomena (DeMers, 2016). GIS learning material must be developed by the teacher to improve the quality of learning (Bednarz et al., 2004; Dölek & Demir, 2011; Susiati, Utaya, & Susilo, 2016). Other experts say that by learning GIS through 3D maps, students are able to read maps and understand the information on the map (Carrera, Avarvarei, Chelariu, Draghia, & Avarvarei, 2017). Questions that contain elements of spatial thinking are needed in GIS learning materials in senior high school.

To meet competency standards of the latest National Curriculum, educators need to create an integration between skill and the use of geospatial technology by using GIS to teach geography. This is the goal of the current National Curriculum in Indonesia to improve students' skills through learning geography with geospatial technologies, such as GIS, remote sensing, and Global Positioning System (GPS) (Baker et al., 2015; Jadallah et al., 2017). The implementation of computer-based GIS learning must be done in the classroom; it has a positive impact on students' understanding and creates an effective learning (Demirci, 2011; Demirci, Karaburun, & Ünlü, 2013; Demirci, 2015). One of the positive impacts is that students can learn immediately to create maps with GIS in the computer laboratory. As a result, students' skills can increase in creating maps. Therefore, it is necessary to improve or develop GIS learning material that contains spatial thinking questions. This can be done by using the component of spatial thinking as a basis for students to study geography. In addition, the questions should be developed in accordance with the objectives of the curriculum (Sitepu, 2012); for example, using geospatial technology in learning geography.



Ideally, GIS learning material questions must contain three components of spatial thinking: concepts of space, use of representation tools, and reasoning processes (Scholz et al., 2014). The questions compiled require students to use GIS for creating map to solve geosphere problems proposed through the developed questions. For example, student could use GIS to map densely populated areas around schools. From that activity, students could use spatial thinking to create and complete the map (Battersby, Golledge, & Marsh, 2006; Lubienski & Dougherty, 2009).

GIS learning material includes three components: 1) GIS concept, including definition, component, software, and hardware; 2) the data used in GIS, including spatial and non-spatial data; and 3) data source, including remote sensing data, field measurement using GPS, and terrestrial data. The learning material is the basis for utilizing GIS in daily life in areas such as environmental management. To utilize GIS, spatial thinking must become part of the learning material questions. First, concepts of space: in this activity students answer questions related to non-spatial, spatial primitives, simple spatial, and complex spatial. The questions are based on the information contained in the map (Gillen, Skryzhevskaya, Henry, & Green, 2010). Second, using GIS to create a map: the map is made by following GIS subsystems processing and output. Students are provided with tutorials in creating a thematic map to improve students' ability. Third, processes of reasoning: using the map they generated, students are assigned in groups to reason on the phenomena drawn on the map in groups. The reasoning process starts from input, processing, and output based on the questions given by the teacher.

### **Conclusion**

Generally, GIS learning material questions in senior high school geography textbooks in Indonesia have low levels of spatial concepts and are ineffective in the development of geographic skills. This weakness affects students' ability to acquire the competent geographic skills. GIS learning material questions in geography textbooks should be designed using questions that can represent spatial thinking and high-level thinking processes. GIS learning material questions that are designed using spatial thinking taxonomy are effective tools to help students learn GIS to improve geographic skills. Therefore, based on our research, we developed recommendations for the implementation of taxonomy of spatial thinking in geographic skills education. First, the teacher must evaluate and design GIS learning material questions using taxonomy of spatial thinking. Second, spatial thinking is the foundation in building important geographic skills; spatial thinking skills must be developed in schools. Teachers can foster this development in compiling questions assigned to students. Third, the

design of GIS material questions should focus on high-level thinking processes; for example, with the overlay technique, students are assigned to create a thematic map.

Assignments like these can trigger high-level thinking that integrates the complex spatial component by using spatial representation tools and cognitive processes to create maps and explaining phenomena drawn on the map. To achieve the competency in creating maps, schools must be provide computer laboratories equipped with GIS. This learning environment will give students the tools to learn and explore geographic knowledge. In this environment, teachers can help students meet the geographic skill standard in the National Curriculum. In addition, government agencies such as the National Education Standards Agency must determine the standard questions in geography textbooks that focus on spatial concepts to represent high-level spatial thinking and the teacher must be able to design GIS learning material questions using taxonomy of spatial thinking.

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