Designing Geospatial Technology Learning Material Based on Spatial Thinking for High School Students

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The need for technology geospatial is of particular concern in geography education currently. However, in learning geography in high school, not much learning material is found in Indonesia. Therefore this study aims to: (1) design and develops geospatial technology learning materials based on spatial thinking for high school students, (2) determine the effectiveness of geospatial technology learning materials based on spatial thinking on geography skills of high school students. This study uses a research and development (R&D) approach with the ADDIE model (analyze, design, develop, implement, evaluate) to design research procedures. Data were collected using a Likert scale and test, then the data were analyzed using descriptive statistics. The results show that geospatial technology learning materials based on spatial thinking are effectively used in learning geography and can improve geography skills in create maps, for example, maps of the school environment. This is caused by contextual learning which results in more interesting learning and students are motivated to learn using geospatial technology. Therefore, for stakeholders in education, such as government, schools, and geography teachers, it is recommended to use geospatial technology learning materials based on spatial thinking in geography learning as a supplement to teaching materials in high school.

Keywords: *Designing, Geospatial Technology, Learning Material, Spatial Thinking*

Introduction

In Indonesia, one significant change in the national curriculum is the revision of the 2013 curriculum in 2016, as project-based learning is highly recommended to be applied in schools (Kamil, Putri, Ridha, Utaya, Sumarmi, & Utomo, 2020). Creating maps and analyzing the information contained in maps is a goal in completing projects collaboratively. Thus, spatial thinking is one method that can be used to do this. Spatial thinking can be defined as spatial

concepts, spatial representation, and spatial reasoning (Lee & Bednarz, 2009; Metoyer & Bednarz, 2017; Moore-Russo et al., 2013). Spatial concepts are fundamental in geographic information systems namely about the distance, coordinates, and dimensions of an object (Lee & Bednarz, 2012). Spatial representation relates to the ability to represent geographical data through maps, graphs, and their relationship to the data used (Metoyer & Bednarz, 2017). Spatial reasoning means the ability to manipulate, interpret data, and show or display data (Golledge, 2002). The development of geospatial technology learning materials has a close relationship with spatial thinking. The relationship can be seen from the components of spatial thinking that can be integrated into learning material (Jo, Bednarz, & Metoyer, 2010; Hong, 2017; Ridha, Utaya, Bachri, & Handoyo, 2019b). Integration is done by placing assignments arranged based on the perspective of spatial thinking. Three components of spatial thinking must be integrated into geospatial technology learning materials, namely concepts of space, tools of representation, and processes of reasoning (National Research Council, 2006; Jo & Bednarz, 2009; Jo et al., 2010; Scholz, Huynh, Brysch, & Scholz, 2014).

Concepts of space is a student activity to answer questions about location, distance, patterns, affordability, morphology, spatial association, connection & linkage, and relationships of a geosphere phenomenon. These questions are classified as nonspatial, spatial primitives, simple-spatial, and complex-spatial. Using tools of representation is a student's activity in representing geographic phenomena using GIS software. This activity is realized through laboratory-based learning that requires skills in operating GIS software, so students are able to create maps, tables, sketches, diagrams to explain and identify objects on the map and their relationship with space. The process of reasoning is very important in learning to mention, explain, create, and evaluate knowledge, for example explaining information on the map (Metoyer & Bednarz, 2017). The reasoning is an activity of interpreting the information contained in maps, so that information is found, for example, the distribution of animals and plants in Indonesia. The reasoning shows the levels in building knowledge, namely input, processing, and output. Processes of Reasoning that include low-level thinking (input), such as recognizing, defining, and registering, as well as higher-level thinking (processing & output), such as evaluating, synthesizing, creating, planning, and generalizing (Jo & Bednarz, 2009; Metoyer & Bednarz, 2017).

Spatial thinking is a form of thought that is defined as knowledge, skills, to use the concept of space such as distance; orientation; distribution; and associations, the use of representation tools such as maps; chart; and diagrams, conducting reasoning processes (cognitive processes to facilitate problem-solving and decision create) to compile the problem formulation, find answers and express solutions to spatial problems (Collins, 2018). Spatial thinking becomes a new foundation that can be used in developing geography skills (Jo et al., 2010). The above opinion shows the importance of designing and developing geospatial technology learning materials based on spatial thinking, to improve geography knowledge and skills. In addition, students are able to convey spatial information through thematic maps that have been made. Thus, spatial thinking in learning can help students in understanding geospatial technologies

which include GIS, remote sensing, and GPS, for example identifying location, scale, and distance (Golledge, 1995, 2002; Sinton, 2015).

Currently, students use geospatial technology such as GPS and Google Earth on mobile to find out the location. Besides, students also use GPS to identify soil types in the field, such as vertisol soil types (Utomo, 2020). The integration of geospatial technology and spatial thinking in geography is an effort to improve geography skills in the form of knowledge and develop the ability to create maps (Kamil, Utaya, Sumarmi, & Utomo, 2020b). For example mapping a tsunami-prone area, if students are in a tsunami disaster zone, such as the city of Banda Aceh (Kamil, Utaya, Sumarmi, & Utomo, 2020a). Map of volcanic disaster-prone areas, if students are in a volcanic disaster location, for example, the Gamalama volcano on Ternate Island; Mount Bromo in Malang Regency.

Other uses of geospatial technology are digital maps and virtual globes. Digital maps and virtual globe can be accessed via mobile, for example, Google Maps and Google Earth. Both of these media can improve spatial abilities and geography skills (Collins, 2018). Since the latest national curriculum was implemented in 2013, there have not been many studies on geospatial technology learning conducted in Indonesia, especially research that focuses on geospatial technology teaching materials used in high school geography learning both internationally and nationally. This can be seen from the publication of books chapter, published by Springer on international perspectives on GIS teaching and learning in secondary schools which shows 33 countries in the world discussing GIS learning in schools (Milson, Demirci, & Kerski, 2012). However, in this publication, Indonesia did not contribute to GIS learning or did not explain its views on GIS learning in schools. Student involvement in the use of GIS-Story maps causes students to see geographical, cultural relationships between maps, their lives, and additional connections outside the classroom (Egiebor & Foster, 2019). The implementation of geospatial technology in learning geography has different variations between countries. The difference is due to the lack of infrastructure availability and the weak competence of teachers in using geospatial technology (Chen & Wang, 2015), so this research needs to be carried out in Indonesia.

Many theories contribute to the design of geospatial technology learning materials based on spatial thinking such as communication theory, theories related to cognitive psychology, social learning theory, and human development theory (Branch, 2009). The learning theory used is an approach in building spatial thinking in designing and developing geospatial technology learning materials as a supplement to geography teaching materials in high school. There are four theories used, namely: Nativist, Piagetian, Vygotskyan and interactionist (Kim, Bednarz, & Kim, 2012). The nativist theory holds that every child born has spatial abilities. This is increasing when the child is growing up. Children are born with several types of spatial abilities, although abilities can develop with age and experience, and there are starting points that are biologically determined and can represent existing objects (Spelke & Newport, 1998; Metoyer, 2014). With this theory, geospatial technology materials can be integrated with spatial thinking

components. The component includes the concept of spatial thinking, the use of representation tools, and reasoning.

Piaget's Theory argues that children understand space by paying attention to the topological properties of objects and spaces rather than their matrix properties (Piaget & Inhielder, 1967). For example, students can understand the material with special attention to the teacher's explanation or with the guidance given. Thus the application into geospatial technology learning material is content arranged according to the order of science or material described, so that students more easily learn it. Piaget's Theory also emphasizes the provision of special guidance in learning activities to achieve learning objectives (Piaget & Inhielder, 1967; Kim et al., 2012). Specific guidance referred to can be interpreted as the use of learning methods recommended following the material to be taught, for example, GIS material, remote sensing, and GPS.

Vygotsky's theory (sociocultural theory) provides many opportunities for social and cultural development in learning. Another opinion explains that this theory emphasizes social and cultural influences on the intellectual development of individuals through cultural tools such as language and maps (Gauvain, 2008). Cultural tools are objects that are produced by culture, both thought, and technology. Cultural tools as objects or artifacts provided by culture, such as literacy and technology, which support thinking and regulate interactions between individuals in the world (Gauvain, 2008).

The interactionist theory is a synthesis of the Nativist, Piagetian, and Vygotskyan theories (Newcombe, 2002; Newcombe & Learmonth, 2005; Kim et al., 2012). This theory emphasizes that the innate abilities possessed by a child as well as environmental conditions must be optimized, in addition to optimizing these abilities can use tools as suggested by the Vygotskyan theory. Interactionists recognize the potential for innate abilities but also emphasize environmental influences in increasing children's spatial knowledge (Kim et al., 2012). These two factors are thought to interact to develop children's spatial competence. Also, interactionists believe that cultural tools such as maps also play an important role in the development of spatial abilities, mostly covering Vygotskyan. Combining existing capabilities and environmental use with cultural tools, the spatial ability can be improved. The intended cultural tool is in the form of geospatial technology produced by humans, such as GIS, remote sensing, and GPS. The influence of the environment and the use of technology can accelerate the ability of students in spatial thinking. The interactionist approach recognizes that individuals have different starting points for spatial thinking, but this skill can be improved through training and mentoring conducted by teachers (Metoyer, 2014). Based on the problem description, the research question in this study is how to design and develop geospatial technology learning materials for high school students in learning geography? Therefore, the objectives of this study are: (1) designing and developing geospatial technology learning materials based on spatial thinking for high school students. (2) knowing the effectiveness of geospatial technology learning materials based on spatial thinking on the geography skills of high school students.

Method
Research Design

This research used a research and development (R&D) approach. The R&D approach produces innovations in research that give strength to competitiveness in the world of education. R&D is a systematic, structured, and measurable effort to trigger and create an innovation (Putra, 2011). To design R&D, this research uses ADDIE design models (analyze, design, develop, implement, evaluate) (Branch, 2009; Sofyan et al., 2020). The ADDIE model can effectively guide product development. This is caused by the concept of development carried out procedurally. ADDIE is a process that serves as a framework for complex situations and is very suitable for developing educational products and other learning resources (Branch, 2009).

The ADDIE model is used to design and develop geospatial technology learning materials based on spatial thinking to produce effective learning products. The ADDIE model is used because it has a systematic step in development, so the learning material is more quality. ADDIE is a concept used to develop products in learning, such as geospatial technology learning material. The ADDIE concept is applied to build performance-based learning or produce a product. The educational philosophy for the ADDIE application is that deliberate learning must be student-centered, innovative, authentic, and inspirational. Creating products using the ADDIE process is one of the most effective tools today (Branch, 2009) because ADDIE can easily process frameworks that are suitable for complex situations, it is very appropriate to develop educational products and other learning resources (Reinbold, 2013; Campbell, 2014).

Analyze aims to determine the needs in designing and developing geospatial technology learning materials based on spatial thinking. Requirement analysis (need analysis) which was carried out consisted of two aspects, namely: (1) evaluation of spatial thinking components on assignments in GIS material, and (2) geography education student responses to spatial thinking-based geospatial technology learning materials in high school. The design aims to formulate learning objectives as outlined in learning material and design geospatial technology learning materials that contain components of spatial thinking. The development phase aims to construct geospatial technology learning materials which include geographic information systems (GIS) materials, remote sensing, and global positioning systems (GPS). The learning material developed consists of three frames that must be met, namely organization, format, and quality. At the developing stage, the design expert, language, and material or content are validated. Implement aims to implement geospatial technology learning materials that have been tested. Evaluate aims to evaluate learning outcomes using learning material that has been developed. Figure 1 explains the procedure in designing and developing geospatial technology learning materials based on spatial thinking.

Figure 1. Procedure for Designing and Developing Geospatial Technology Materials Using the ADDIE Model
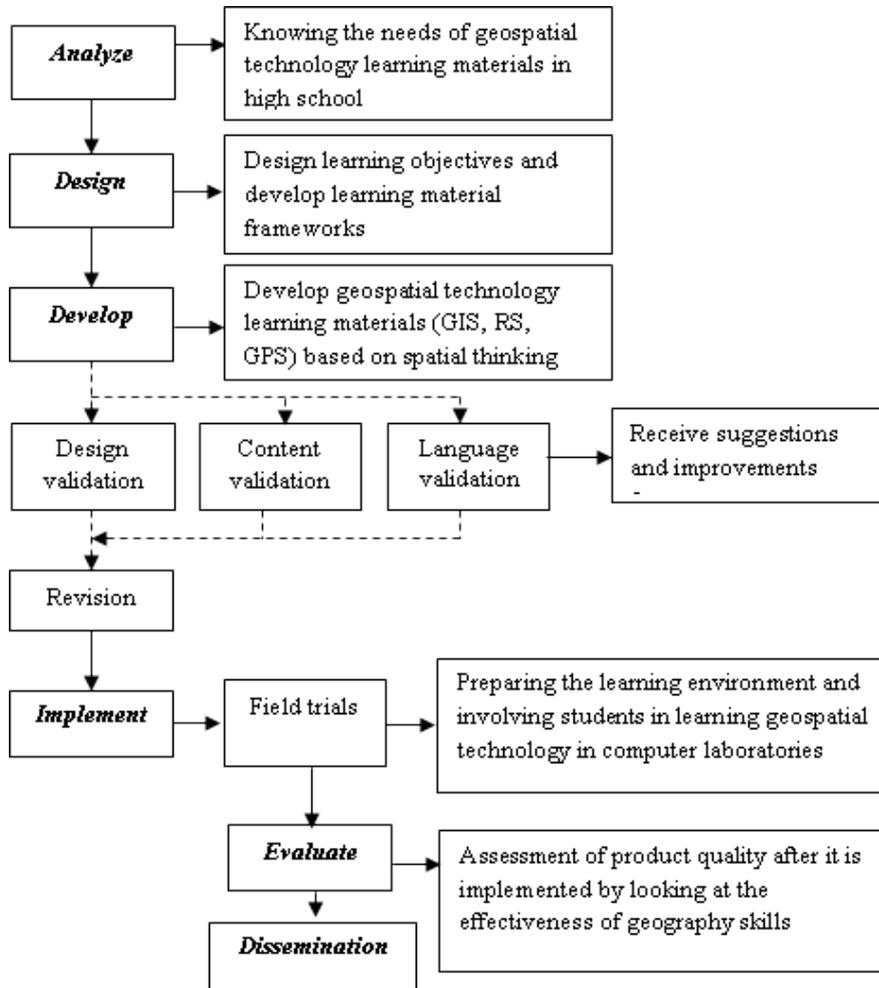

Data Collection

Data is collected from the responses of experts (expert validation), teachers, and students. Respondents consisted of 3 experts, 2 teachers, and 73 students to provide responses to geospatial technology learning materials. Before the trial, the expert validation was first performed consisting of: linguists, content of learning materials, and design . The expert functions as a validator who provides input on products that have been developed. Linguists provide input on aspects of punctuation, vocabulary, sentences, and paragraphs. Material experts provide input on the content of geospatial technology, namely GIS, remote sensing, and GPS, and its relation to spatial thinking. Design experts provide input on aspects of the design of learning materials, namely: organization, format, and quality. The trial design used was a field trial,Tthis trial aims to determine the effectiveness of geospatial technology learning materials based on spatial thinking on geography skills competencies. Therefore, in this study, the field trial subjects were taken in more than one class, around 73 students. The data obtained

in this trial in the form of test results and questionnaire data to see the effectiveness of learning material.

Instruments

The instrument at the trial stage was a questionnaire using a Likert scale and a test of geography skills in create maps using GIS software. The questions format used are essays, to see students' ability to solve problems with spatial thinking approaches and geography skills in using GIS applications. The Likert scale is illustrated in Figure 2 (Purwanto, 2014).

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Figure 2. Illustration of a Likert Scale
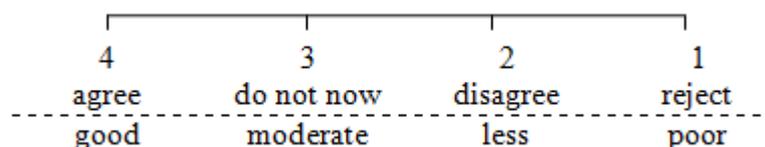
Data Analysis

Data analysis was performed with descriptive statistical techniques to process the results of the responses of experts, teachers, students, and the results of geography skills tests. Expert, teacher, and student response data were obtained from questionnaire answers. While the geography skills test results data obtained from answers to questions and student activities in create maps. Questions are made in the form of essays for 5 questions. Mapping activities are assessed through maps created by students using GIS software.

Result

The Need for Geospatial Technology Learning Material Based on Spatial Thinking

Geospatial technology learning material needs based on spatial thinking are seen from (1) evaluation of GIS material using the taxonomy of spatial thinking, and (2) knowing the need for geospatial technology learning materials based on geography education students' responses to high school geography teaching materials. Evaluation of questions is only done on GIS material because GIS is part of geospatial technology materials in high schools. The need for learning material is seen from the perspective of geography education students. Students are used as subjects to find out their views on the novelty of geography teaching materials used in schools (Ridha, Putri, Kamil, Utaya, Bachri, & Handoyo, 2020). Geography education at universities aims to produce pre-service teachers who are creative, innovative, and responsible for science in the field of geography (Purwanto et al., 2015; Mitchell, 2018). That is why the geography education curriculum at the university pays attention to the design of learning

materials that will equip students when they become teachers (Whalley et al., 2011; Sun et al., 2019).

Based on evaluations, GIS material questions focus on low levels of spatial thinking, and the majority do not use tools of representation and low-level reasoning processes (Ridha et al., 2019a). Thus it can be seen that the questions are designed not to use the taxonomy of spatial thinking so that geography skills cannot be measured. The three components of spatial thinking that must be contained in a GIS learning material questions are concepts of space, tools of representation, and processes of reasoning. Each component has subcategories to create it easier to identify the level of spatial thinking. For example concepts of space (i.e. non-spatial, spatial primitives, simple spatial, complex spatial), using tools of representation (i.e. use and non-use), and processes of reasoning (i.e. input, processing, and output).

GIS learning materials based on spatial thinking are needed by geography education students. This need is based on the current competence of students, namely using basic GIS, while the expected learning goal is to be able to conduct spatial data analysis using GIS (Ridha et al., 2020). Geography education students are prepared to become geography teachers in schools that can teach GIS to students so that GIS does not only develop in universities but also develops in schools. Therefore the importance of designing and developing geospatial technology learning materials that are creative, innovative, easy to understand, and contain components of spatial thinking both in the content, assignment, and evaluation sections.

Design of Geospatial Technology Learning Material Based on Spatial Thinking

This section explains the design of geospatial technology learning materials based on spatial thinking. In designing learning material, it is necessary to formulate learning objectives. Learning objectives contained in learning materials are arranged by describing basic competencies into indicators and synthesizing learning materials from existing textbooks. The design stages also design the learning material framework. The learning material framework includes organizing, determining format, and quality.

The conceptual model of geospatial technology learning material design consists of 6 categories and 14 subcategories which must be followed in the development of geospatial technology learning materials. The 14 subcategories are integrated through three components of spatial thinking and three design learning materials according to the ADDIE model. This integration becomes an innovation in the design of geography learning materials in general and in particular geospatial technology learning materials. Innovation can be seen from the role of the spatial thinking component in learning material create it easier for students to understand geospatial technology materials because the geography approach includes spatial, environmental, and regional complex approaches. One of these approaches is used in developing geospatial technology learning materials. This is why this conceptual model is an innovation in geography

education. In brief, the conceptual model of spatial thinking-based geospatial technology learning material development is shown in Figure 3 (Ridha, Putri, & Kamil, 2019).

Figure 3. Conceptual Model for Developing Geospatial Technology Learning Material Based on Spatial Thinking
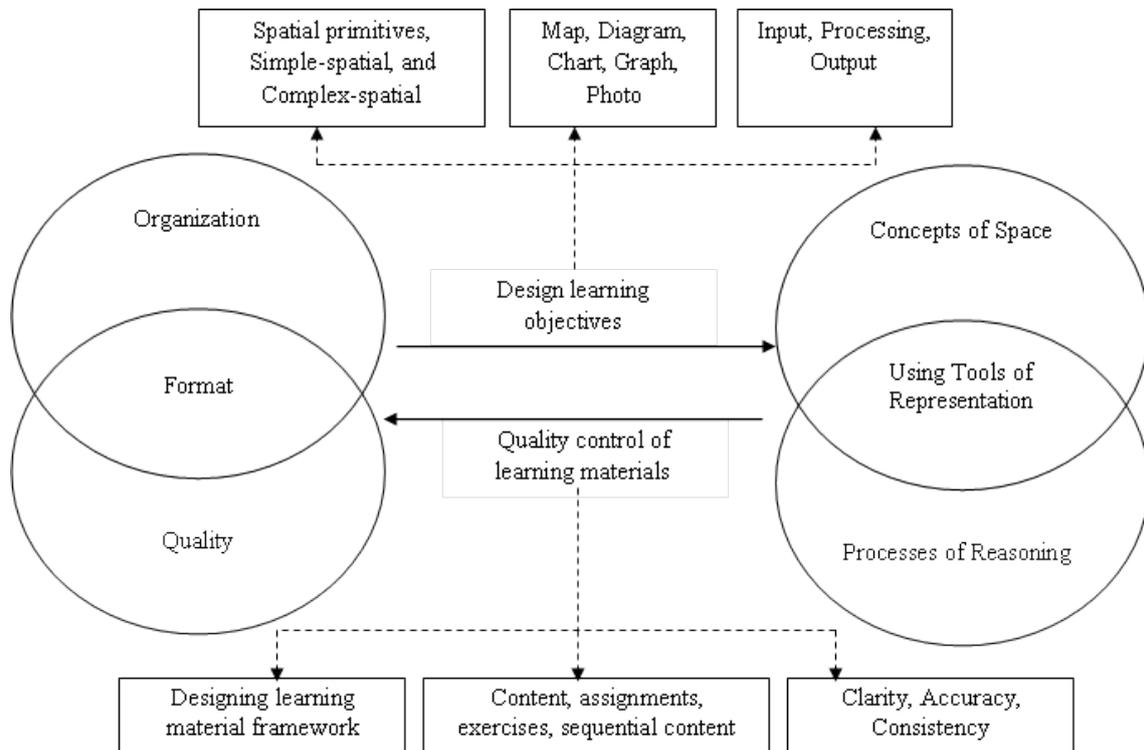
Next, do design learning objectives. The first step in designing learning objectives is to choose the basic competencies to be measured, and then to determine the indicators used as a reference to assess the achievement of minimum or basic competencies. The design of learning objectives is guided by the theory of learning behaviorism that uses the characteristics of the audience acting as students, behavior, conditions, and degrees as desired. Table 1 explains how to designing learning objectives.

Table 1: Designing Learning Objectives

Indicator	Behavior	Object	Condition	Criteria
1. The benefits of learning geospatial technology	Explain	GIS, remote sensing, and GPS	Given five minutes	Correctly
2. Determine the location of settlements in disaster-prone areas	Determine	Map of disaster-prone areas	Given five minutes	Correctly

Based on Table 1, the learning objectives arranged into one sentence that is connected with students as follows (Table 2).

Table 2: Application of Components of Spatial Thinking in Learning Objectives

Example Learning Objectives	Component of Spatial Thinking	
	Subcategories	Taxonomy
Given five minutes, students can correctly explain the benefits of learning geospatial technologies such as GIS, remote sensing, and GPS.	Non-spatial Non-use Input	- - Explain

The learning objectives above do not show the component of spatial thinking, because they do not contain spatial concepts, do not use tools of representation, and cognitive processes at a low level. Examples of geographic learning goals based on spatial thinking can also be explained as follows. For example, "Based on the map of disaster-prone areas below (Figure 4), given five minutes, students can determine the safe location of settlements in disaster-prone areas correctly".

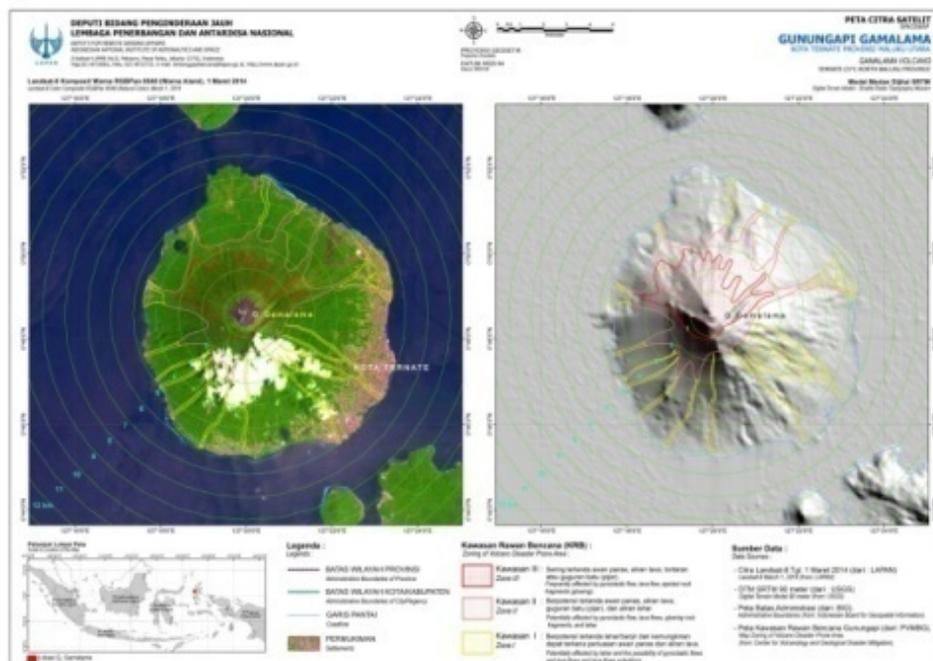**Figure 4.** Map of the Gamalama Volcano Disaster-Prone Areas

Figure 4 shows a geography learning objective that is integrated with the components of spatial thinking and their respective taxonomies, namely complex-spatial (i.e. spatial association), using tools of representation (i.e. maps), and output (i.e. prediction). The purpose of this

learning shows at a high level of thinking, so students easily understand the subject matter of geography. The components, subcategories, and taxonomy of spatial thinking are shown in Table 3 below.

Table 3: Taxonomy of Spatial Thinking

Components of Spatial Thinking		Taxonomy
Category	Subcategory	
1. Concepts of Space	Non-Spatial	-
	Spatial primitives	Place-specific Identity, Location, Magnitude
	Simple-Spatial	Distance, Direction, Connection & Linkage, Movement, Transition, Boundary, Region, Shape, Reference Frame, Arrangement, Adjacency, Enclosure
	Complex-Spatial	Distribution, Pattern, Dispersion & Clustering, Density, Diffusion, Dominance, Hierarchy & Network, Spatial Association, Overlay, Layer, Gradient, Profile, Relief, Scale, Map Projection, Buffer
2. Using Tools of Representation	Use	Map, Diagram, Chart, Graph, Photo
	Non-Use	-
3. Processes of Reasoning	Input	Name, Define, List, Identify, Recognize, Recite, Recall, Observe, Describe, Select, Complete, Count, Match
	Processing	Explain, Analyze, State causality, Compare, Contrast, Distinguish, Classify, Categorize, Organize, Summarize, Synthesize, Infer, Make analogies, Exemplify, Experiment, Sequence
	Output	Evaluate, Judge, Predict, Forecast, Hypothesize, Speculate, Plan, Create, Design, Invent, Imagine, Generalize, Build a model, Apply a principle, Complex

Source: Adoption of Jo & Bednarz, (2009)

The Effectiveness of Geospatial Technology Learning Materials on The Geography Skills of High School Students

- ***Expert Responses***

Based on the results of the design validation, the learning material is very valid with a score of 89%, and a minor revision is recommended. Minor revisions need to be made to the sections: image captions, and image proportions. The expert suggested that the picture caption is better

to use letters that are smaller than the main text, for example using font size 11. This is to distinguish between the main text and the image caption. Also, the distance between the captions of images and illustrations needs to be adjusted, meaning that they are not too close or too far away. So that images illustrations are more interesting and easier for students to understand. The consistency of images needs to be maintained in order so that the use of pages is more effective and messages from images can be understood by students.

Based on the results of language validation, the learning material is very valid with a score of 95%, and a minor revision is recommended. This is because in general, the Indonesian language used is effective. Effectiveness is characterized by the accuracy of the use of terms, vocabulary choices, structuring sentences, and the accuracy of using command sentences. Writing the main idea in a paragraph can create it easier to understand the contents of the paragraph. The main idea is at the beginning of the paragraph and followed by a supporting sentence. The supporting sentence serves to explain the main idea, so students understand the contents of the paragraph.. Also, there is a continuity between one paragraph with another paragraph. This results in students understanding the whole paragraph. Minor revisions need to be made to the sections: use of spelling, punctuation, and writing of foreign words.

Based on the results of the score calculation, the learning material is very valid with a score of 85% and it is recommended a minor revision and inland material. This is because the content in geospatial technology learning material is well explained. The components contained in geospatial technology learning materials consist of two, namely: (1) the contents of geospatial technology, and (2) the content of component of spatial thinking in learning material. The contents include the suitability of data/facts, the truth of the concept of geospatial technology (GIS, remote sensing, and GPS), the accuracy of generalizations, wrinkles, coverage and accuracy, the ropes of create map tutorials, the suitability of images with the material, the suitability of learning objectives with exercises, the material relevant to geography skills competency, number of exercises/assignments, presentation of examples relevant to the material.

- *Teacher Responses*

According to the teacher the geospatial technology learning material is effectively used but needs minor revisions. This can be seen from the acquisition of a score of 75%. Revision needs to be done because there are still shortcomings, both organizing, format, and quality. Some things that need to be revised are the glossary and the size of the textbook. The following is a summary of teacher responses to geospatial technology learning material.

> in bahasa: *Glosarium perlu diperdalam dengan menjealaskan lebih banyak istilah yang digunakan dalam materi teknologi geospasial. Sedangkan ukurannya perlu diperkecil agar praktis dibawa oleh siswa.*

(translation: The glossary needs to be detailed by realizing more terms used in geospatial technology materials. While the size needs to be reduced so that it is practically carried by students).

- *Student Responses*

According to students geospatial technology learning materials based on spatial thinking are effectively used in learning geography, but minor revisions need to be done. This can be seen from the acquisition of a score of 76.49%. Minor revisions are needed because, there are still shortcomings, such as organizing, attracting the appearance of covers, images, image sizes, and glossaries. Organizing is incomplete, for example, in the glossary, there are still words that need to be reproduced. This needs to be done to improve student understanding. According to students, the size of the image used is not the same size but does not reduce the meaning or information.

- *Improved geography skills through learning geospatial technology*

Geography skills are the ability to understand and create maps that are applied in learning activities, both using digital maps and analog maps. Activities are classified into two, namely: answering questions that contain components of spatial thinking (test), and create maps based on observations of the school environment. Five questions are answered in the form of essays. The question was designed using the taxonomy of spatial thinking. The thematic map created is a map of the school area. As a group of students observes the school building and the surrounding environment. Geography skills are measured by looking at students' activities in create maps and tests after learning is carried out to measure geography skills in create maps with GIS software.

Based on the results of the geography skills assessment, showing of 73 students, 69 students completed, while those who did not complete as many as 4 students. This data shows the majority of students are able to create maps by following the geospatial technology learning materials that have been developed so that geography skills can be improved. Based on these results, the classical completeness is 94%. Thus, geospatial technology learning materials are very effectively used in learning geography to improve geography skills. The factor that causes geospatial technology learning materials to be effectively used in geography learning is an increase in students' geography skills which is characterized by the ability to create thematic maps, so therefore curriculum objectives can be achieved.

Geography curriculum standards expect the achievement of geography skills. Achievements are made by implementing geospatial technology learning which includes: GIS, remote sensing, and GPS in learning geography in high school. The results showed that: 92% of students had never learned geospatial technology before, 75% of students said their learning was interesting, 18% was very interesting, and 7% was quite interesting. Direct learning using computers can

increase motivation to learn, this is evidenced by 83% of students motivated to learn, 8% are highly motivated, 8% are quite motivated, and 1% are not motivated so that 86% of students easily understand geospatial technology materials when learning to use computers and using the GIS application, 7% is very easy, and 7% is quite easy. Figure 5 explains students' responses to the learning of geospatial technology implemented using GIS software.

Figure 5. Student Responses to Learning Geospatial Technology Using GIS Software
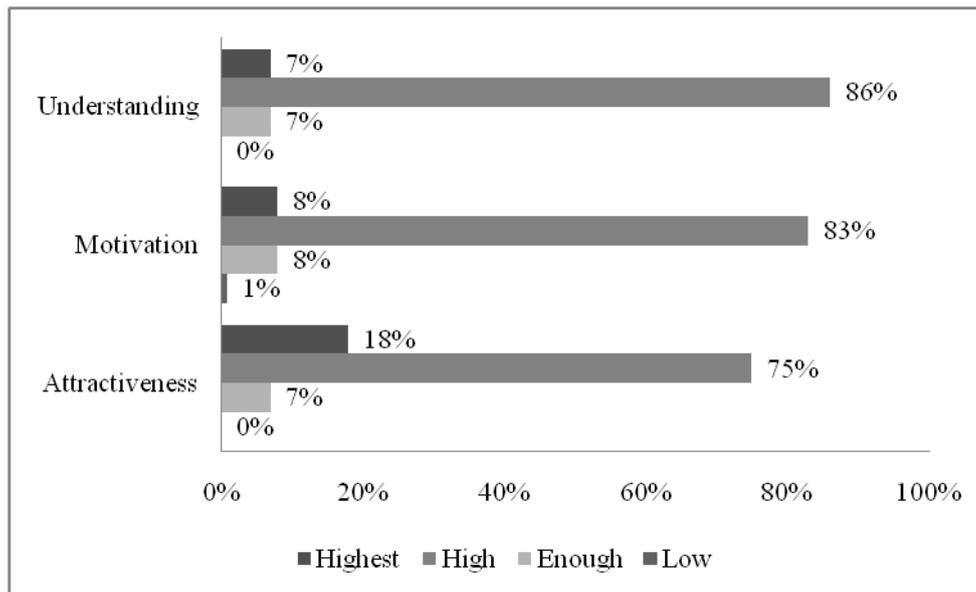

Figure 5 shows the attractiveness of learning geospatial technology using GIS software, student motivation, and student understanding of the material. The three aspects showed an increase in both the attractiveness of learning, motivation, and understanding of the material in learning geospatial technology using GIS software. That is why the classical completeness of geospatial technology learning can be achieved. However, students also expect the school to provide a means of learning geospatial technology, such as the GIS program in computer laboratories, because this learning is very interesting, thus increasing motivation to learn geospatial technology and being able to improve geography skills.

The use of geospatial technology requires a sustainable response to the advancement of geographic education innovation (Hauselt & Helzer, 2012). The use of GIS is a geospatial technology that can help students understand the principles of geography, for example, the principle of interrelation, which explains the relationship between one phenomenon and another (Patterson et al., 2003). Students who study GIS show more development in spatial ability and map analysis compared to students who learn GIS in conventional ways (Jadallah et al., 2017). Figure 6 is the result of learning geospatial technology using GIS software for mapping the school environment.

Figure 6. Map of Schools Created By High School Students Grade X

Discussion

Overall, GIS learning material questions with spatial concepts in high school geography textbooks in Indonesia are still low and unable to build geography skills (Ridha et al., 2019a). This is a weakness for GIS learning material that has an impact on the achievement of geography skills (Ridha et al., 2020). GIS learning material should be designed in a geography textbook using questions that can represent spatial thinking and high-level thinking processes (Jo et al., 2010; Ridhaet al., 2019a). GIS learning material questions that are designed using the taxonomy of spatial thinking are effectively used in GIS learning to build geography skills (Scholz et al., 2014). Therefore, the important thing to do is: first the teacher must evaluate and be able to design GIS learning material questions using the taxonomy of spatial thinking because the taxonomy is a good tool for designing questions with spatial concepts to build geographic skills (Jo & Bednarz, 2009). Second, spatial thinking as a foundation for building

important geographic skills and must be developed in schools (Jo et al., 2010; Metoyer et al., 2015). Development can be done through special attention by the teacher to arrange the questions assigned to students. Third, the design of GIS learning material questions is expected to focus on high-level thinking processes, for example with overlay techniques, students are tasked with create thematic maps. In addition, it can also using complex spatial concepts, such as explaining spatial distribution; pattern; and spatial associations, using representation tools in learning, such as maps; picture; and graphs, using high-level cognitive processes, such as output which includes planning; designing; and evaluate. (Gillen et al., 2010).

Such questions can lead to higher-order thinking that integrates complex spatial uses of spatial representation tools and cognitive processes by create maps and explaining phenomena drawn on maps (Jo et al., 2010; Scholz et al., 2014). Also, to realize the achievement of competency skills, school support is expected to prepare a learning environment in the form of preparing a computer laboratory equipped with geospatial technology (Jo & Hong, 2020; Osborne et al., 2020). This creates it easy for students to learn and explore knowledge, and the teacher can carry out learning as expected in the curriculum for the achievement of geography skills. Also, governments such as the *Badan Standar Nasional Pendidikan* (BSNP) in Indonesia must determine the question standards in geography textbooks that focus on spatial concepts to represent high-level spatial thinking, and teachers must be able to design GIS learning material questions using the taxonomy of spatial thinking. The implications of the components of spatial thinking contained in GIS learning material are characteristics that distinguish it from other geography learning materials. Components of spatial thinking become key in cognitive skills (National Research Council, 2006).

The conceptual model of developing geospatial technology learning material consists of category and subcategory components (Ridha et al., 2019). For example, if the category is a concept of space, then the subcategory is spatial primitive, simple-spatial, and complex-spatial (Jo & Bednarz, 2011). The two components are related, namely the actualization of the design of learning objectives, the framework, and the contents described (Branch, 2009). The organizing and format categories are the basis for designing the learning material framework, while the component of spatial thinking is the basis for designing learning objectives. To achieve the learning objectives, geospatial technology learning materials are designed along with exercises and assignments conducted by students. The quality category is a control of the design of the framework and learning objectives that emphasize the clarity, accuracy, and consistency of geospatial technology learning materials.

The implications of the design of geospatial technology learning materials in schools can be done in all classes in geography learning. This means that this design can also be used to design other geographic materials. The implementation reflects the readiness of teachers and schools to carry out the task of creating effective and interesting learning activities in improving geography skills (Bodzin, 2011; Metoyer et al., 2015). Learning in the classroom cannot be

based on one teaching material, but teachers need to develop teaching materials that are creative, innovative, and following student needs (Wilder et al., 2003).

The product produced in this research is geospatial technology learning material based on spatial thinking. The component of spatial thinking in learning material are concepts of space, using tools of representation , and processes of reasoning . The component of spatial thinking is contained in the content, namely in paragraphs, questions, and assignments. The presence of spatial thinking in geospatial technology learning materials proves that there is an increase in geography skills in high school students. This is indicated by the students are able to create maps using geospatial technology.

After following the development phase that refers to the ADDIE model that starts from the needs analysis, develops content, validation, and trials, it produces geospatial technology learning material that can be used in geography learning in high school. This is because geospatial technology learning material contains GIS, remote sensing, and GPS material. Geospatial technology learning materials consist of three anatomies (frames), namely organizing, format, and quality (Branch, 2009; Sitepu, 2012). This frame is used based on the advance organizer theory which explains that learning material follows information from existing general descriptions (Branch, 2009). This means that learning material contains information that is currently developing and following the times. The need for technology is needed by students in learning geography because technology is a tool to understand natural and social phenomena in people's lives. So students can solve various problems because problem-solving ability is also one of the competencies in the 21st century (Salehudin et al., 2020; Yunus et al., 2020). Therefore, geospatial technology learning material is important to be studied by students in learning geography in high school.

Conclusions and Implications

The majority of questions about GIS learning material in high school geography textbooks are low and unable to build geography skills. This is a weakness for GIS learning material that has an impact on the achievement of geography skills. Also, geography education students are prepared to become geography teachers in schools that can teach GIS to students, so that GIS does not only develop in universities but also develops in schools. The design of geospatial technology learning material consists of designing learning objectives and the framework of geospatial technology learning material based on spatial thinking. Learning objectives contained in learning materials are arranged by describing basic competencies into indicators and synthesizing learning materials from existing textbooks.. Based on design validation, geospatial technology learning materials based on spatial thinking can be said to be very valid (i.e. 89%), language validation, very valid (i.e. 95%), and expert validation is very valid (i.e. 85%). According to the teacher, geospatial technology learning materials are effectively used in learning, this can be seen from the acquisition of a score of 75%. According to students, geospatial technology learning materials are also effectively used with a score of 76.49%. From the results of learning, it shows that of 73 students 69 students completed, while those who did

not complete as many as 4 students or classical completeness were 94%. Thus, geospatial technology learning materials are very effectively used in learning geography to improve geography skills. The use of geospatial technology requires an ongoing response to the advancement of geographic education innovation, such as the availability of computer laboratories in schools that support the learning of geospatial technology. Students who use geospatial technology show more development in spatial abilities compared to students who study conventionally. Thus, geospatial technology learning materials are very good/very effective in using geography learning to improve geography skills such as create maps. Therefore, learning geography in schools can use this learning material to improve geography skills.

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