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The importance of designing GIS learning material based on spatial thinking

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Abstract: Currently, GIS (Geographic Information System) learning material is an important component of geography education, therefore geography teachers need to pay attention to this. GIS has a relationship with spatial thinking in which learning GIS can increase spatial thinking skill. However, there are many geography learning materials developed without containing a component of spatial thinking. Therefore, this study discusses the importance of designing GIS learning material based on spatial thinking. Spatial thinking in this study is used as a basis for developing learning material using concepts of space to explain GIS theory and application, using tools of representation, and using processes of reasoning. This study used a descriptive qualitative approach. Data were collected through observation and questionnaire. Data were analyzed by doing reduction and descriptive statistic. The result of calculating the score of the learning material is 77 percent. It means that GIS learning material based on spatial thinking is needed by the student in learning geography. College students in the Geography Education Program are prospective teachers who will teach GIS to students at schools. Thus, they need to develop GIS learning material based on spatial thinking.

1. Introduction

Generally, learning material contains information about thoughts, ideas, or knowledge of the author to be presented to the reader, by using visual symbols in the form of letters, images, or other forms. The main function of learning material is as a medium of information, primarily in the form of handwriting, then printing, and electronics. The presence of learning material, both in printed and electronic forms, has had a major influence on learning and made an increase in the educational revolution [1], [2]. If previously the teacher was the main source of learning, it is now the second main source. This creates the possibility to study without the teacher's presence [3].

In a broader context, learning material contains information that can provide abilities to students in line with the objectives set in the curriculum as well as the stages in achieving educational objectives at the institutional level and national education goals [4]. Therefore, the content of the learning material is an elaboration or description of the subject matter specified in the curriculum [5]. Referring from its contents, the subject matter is one of the learning tools inseparable from the curriculum. Standardized learning material can be used as a means or source of learning to improve and level the quality of national education.

Judging from the content and presentation, the learning material serves as a guide for students in learning and teachers to teach students to study fields or certain subjects [6]. Learning guidelines means which is used by students as the main reference to prepare themselves, both individually and in groups. They use it before classroom learning activities, to interact in the learning process in the classroom, to work on assignments given by the teacher, and to prepare for formative and summative tests or exams [1], [5]. For teachers, the learning material is used as a reference in making learning designs, preparing learning resources, developing contextual learning materials, and compiling evaluation materials [3].

Learning material can be packaged in various forms, one of them is textbooks. There are five benefits of using textbooks (*printed materials*) in learning, namely [6]: (1) Availability, textbooks are



sufficient in availability, which is easy to access at the library. (2) Flexibility, textbooks are arranged regarding the material characteristics and learning objectives. They can help students learn and answer practice questions. (3) Portability, textbooks have decent practicality, it can be brought anywhere. (4) The user-friendly, attractive design makes textbooks interesting. (5) Economical, textbooks are easy to attain. Its prices are inexpensive, even, for now, textbooks have been provided by the government for free without having to buy.

Considering the functions and benefits of textbooks in the learning process, the textbook writers need to strictly refer to learning objectives set in the curriculum to develop the contents of the textbooks. Besides, the fact, update, and accuracy of the information submitted are essentially based on the relevant disciplines. The depth and breadth of learning materials are associated with skills to achieve, suitable learning methods, as well as the language used following students' language skills.

Geography is an effort to provide understanding to students to understand natural features [7]. One component of the geography education system is learning the material. Learning material is a learning resource used in learning [8]. However, learning material is not the only source used in learning [9]. Learning material can be packaged in various forms, both print and digital, such as textbooks, dictates, modules, and student worksheets. Judging from its function the textbook can utilize as a reference book as well as a monograph. Reference books are textbooks that describe a particular science broadly and the monograph is a textbook that is used as supporting material or a small part of a science [10]. For example, reference book geographic textbooks explaining all aspects of geography studies, while the monograph book can be a narrower part of the study of geography, for example, the georeferencing study used in GIS learning [11].

Faculty of Geography Education at the universities aims to produce prospective teachers who are creative, innovative, and responsible in the field of geography science [1]. That's why the geography education curriculum at the university pays attention to designing learning materials that will equip students when they become teachers. Geography education helps to solve environmental problems in learning by asking questions, such as: *what, where, when, why, who, and how*, to develop consequences, policies, awareness and commitment [12]. Thus, geography education remains around meaningful learning; starting from geographic questions through spatial thinking.

Spatial thinking is a combination of the building of cognitive skills through space concepts, the use of representational tools and the reasoning of processes [13], [14]. The role of spatial thinking in the development of learning material is to integrate the components of spatial thinking into the content, assignment section, and evaluation. Spatial thinking consists of three components, namely: the concept of space, tool of representation, and the process of reasoning [13], [15], [14]. The three components form the pattern of the preparation of content and evaluation materials; such as assignments, questions, and exercises [16]–[18].

This study is a need analysis of GIS learning material regarding spatial thinking. Needs analysis is one essential step to determine the skills or competencies for students to enhance their performance or achievements of learning [19]. This can be done if the learning program is seen as a solution to the learning problem being faced [20]. Some of the key questions that must be sought a learning material designer are: (1) Do students need spatial thinking-based teaching materials? (2) Can students achieve learning goals with teaching materials provided so far? (3) What knowledge and skills do they have? (4) What abilities or competencies need to be possessed? Thus, this study aims to determine the needs of GIS learning material based on spatial thinking seen from the students' perspective. The learning materials requirements in question are how necessary GIS learning materials based on spatial thinking are developed? This, thus, is seen from the perception of students who study GIS in higher education.

2. Method

This study used a descriptive qualitative approach. Data were collected by observation. The type of observation used was overt observation, in which the presence of the researcher was known by respondents [21], [22]. Observation aims to see students' perceptions of GIS learning material used. To obtain data, the instrument used was a questionnaire. Data is analyzed by reduction. Reduction means summarizing and choosing the primary findings that are following the research objectives [23], [24]. Thus the reduced data will provide a clearer picture [22]. Besides, descriptive statistics were used to

see the percentage of respondents' answers. Table 1 shows the qualifications of SIG learning material needs based on spatial thinking.

Table 1. Qualification of SIG learning material needs based on spatial thinking

No	Level of Achievement	Qualification
1	80.1% - 100%	Very needed
2	70.1% - 80%	Needed
3	60.1% - 70%	Fairly needed
4	50.1% - 60%	Less needed
5	1% - 50%	Not needed

Source: [25]

To obtain a percentage number, the following formula is used [26].

$$P = \frac{\sum \text{questionnaire's score}}{n \times \text{highest score} \times \text{number of respondents}} \times 100$$

Description:

P = percentage

n = number of questions

3. Results and Discussion

The results of the study are presented to answer the key questions. The question is: are spatial thinking-based GIS learning material needed? What knowledge and skills do you have? What abilities or competencies need to be possessed? Can students achieve learning goals with existing teaching materials? These questions illustrate the importance of developing GIS-based learning materials based on spatial thinking.

3.1. GIS Learning Material Requirements Based on Spatial Thinking

Data on student perceptions are presented in quantitative and qualitative forms. Quantitative data is displayed in the form of the number of question scores and the percentage of students who answered the questionnaire. From the total score, it is known the level of GIS learning material needs based on spatial thinking. The qualitative data is shown through descriptions of GIS learning material that should be developed regarding students' perspectives. Table 2 shows the scores obtained based on student responses from the questionnaire given. The number of students who gave responses was 26 students. While the number of questionnaire items is 5 questions.

Table 2. Presentation of data based on the number

No	Question	Score	
		Σ	%
1	What knowledge and skills do you need to have regarding GIS	98	19
2	Do the materials used help you to improve spatial data analysis skills	78	15
3	Do GIS learning-materials help you achieve learning objectives	72	14
4	Do GIS learning materials help you to improve spatial data analysis skills	92	18
5	Does GIS learning use spatial thinking based teaching materials	59	11
	Total	399	76.7
	Needs		77%

From data Table 2 GIS learning material needs can be calculated as follows:

$$= \frac{399}{5 \times 4 \times 26} \times 100$$

$$= \frac{399}{520} \times 100$$

$$= 77\%$$

The data is also presented in the form of percentages, in which each question is presented with the number of students who answered the questionnaire. This is to show whether learning materials that have been used can improve spatial data analysis skills. From Table 3, it can be seen the need for GIS learning material that can improve spatial data analysis ability. 51 percent of students answered questionnaires with a score of 3, meaning that GIS-based spatial thinking is needed by geography education students in universities to improve spatial data analysis skills.

Table 3. Presentation of data based on the percentage of answers

No	Question	Score			
		1	2	3	4
1	What knowledge and skills do you need to have regarding GIS	1 (4%)	0	3 (12%)	22 (84%)
2	Do the materials used help you to improve spatial data analysis skills	0	3 (12%)	18 (69%)	5 (19%)
3	Do GIS learning-materials help you achieve learning objectives	0	6 (23%)	20 (77%)	0
4	Do GIS learning materials help you to improve spatial data analysis skills	0	0	12 (46%)	14 (54%)
5	Does GIS learning use spatial thinking based teaching materials	6 (23%)	7 (27%)	13 (50%)	0
	Average	1.4 (5%)	3.2 (12%)	13.2(51%)	8.2 (32%)

Table 3 shows the percentage of each question based on the number of respondents. 5 percent of respondents give 1 score; 12 percent gave score 2, and 51 percent gave 3 score; 32 percent chose 4 score. It can be seen that SIG-based spatial thinking learning material is needed by geography education students in universities to improve spatial data analysis capabilities.

3.2. Knowledge and Skills that Have Been Held

The calculation results show that GIS-based learning materials based on spatial thinking are needed by students. This can be seen from the total score of the questionnaire which is 77 percent. This need is based on the competencies of students, namely being able to use basic level GIS. This ability is applied in the students' activities such as doing georeferencing, digitizing (*point, polyline, polygon*), and layout. This ability is not following the intended learning objectives or competencies, that is, being able to use GIS to analyze spatial data, such as buffers and overlays. In the field of knowledge, students can explain the understanding and benefits of GIS, GIS components, and types of spatial data.

3.3. Capabilities or Competencies Needed

Knowledge and skills that students need to have regarding GIS are namely theory, practice, and spatial thinking skills. This can be seen from the percentage of the answers, which are 84 percent. This means that students want to master theory, practice and spatial thinking skills that have relevance. The link is that knowledge is the basis for spatial studies using geospatial technology, such as remote sensing, GIS, and global positioning system (GPS) [27].

Combining existing capabilities and utilizing the environment with cultural tools, spatial abilities can be improved [28]. The cultural tool in the question is in the form of human-generated technology, such as remote sensing which produces satellite images and aerial photographs. Satellite images and aerial photographs are data that can be processed with geospatial technologies such as GIS. Therefore the use of GIS in geography learning can improve spatial thinking skills [29]. The theory of interactionists recognizes that each individual has different spatial thinking skills, environmental influences and the use of technology can accelerate abilities in spatial thinking [30].

The development of GIS learning material should be updated based on the results of the latest research and the development of spatial-based thinking to succeed in improving spatial data knowledge, skills, and analysis skills. Besides, using clear wording can facilitate understanding the learning material. The results of the reduction in student responses to the development of GIS learning materials are as follows:

GIS is the most difficult subject. I hope GIS learning material is developed more creatively, innovatively, pleasantly and easily to understand so that it can have positive impacts on students, teachers, and lecturers. Therefore, there is a book that examines GIS-based spatial thinking.

The above quotation shows the expectations of students towards GIS learning materials that are developed in a creative, innovative, fun, easy to understand, and based on spatial thinking. Creative means having the ability to create learning material that can improve spatial data analysis skills. Innovative means introducing theories, methods, and uses of GIS for spatial data analysis. For example, the use of GIS in the field of disaster to reduce the risk of a tsunami disaster inside planning a coastal disaster prevention forest [31]. Fun learning material is interactive and easily understood learning material [3]. Without teacher guidance, students can use learning materials to study GIS. Thus, students actively carry out assignments in the textbook.

3.4. Achievement of Learning Objectives with Learning Material

Learning material that is being used can improve learning goals. This is seen from the percentage results of 77 percent, meaning that students can understand the material using GIS learning materials that have been used so far. However, students need GIS learning material that is new and following technological developments. Novelty can be given through the results of recent research from reputable sources and the development of spatial thinking based.

3.5. Application Components of Spatial Thinking in GIS Learning Materials

The application of spatial thinking components contained in GIS learning material is a characteristic that distinguishes it from other geography learning materials. The component of spatial thinking is key in cognitive skills. Three components of spatial thinking can be used in GIS learning material, namely the concepts of space, using the tools of representation, and processes of reasoning[17].

Some important things that must be considered in developing GIS learning material based on spatial thinking are: (1) evaluating and designing material using the taxonomy of spatial thinking. Taxonomy is a good tool for designing learning material with spatial concepts to build geography skills [32]. (2) Spatial thinking as the foundation in building important geographic skills and must be developed in higher education [15], [32]. Development can be done through special attention to compiling material. (3) The design of the material is expected to focus on high-level thinking processes, for example, by overlaying techniques.

4. Conclusion

The results of the data analysis showed that GIS learning material based on spatial thinking is needed by geography education students. This can be seen from the total score of the questionnaire which is 77 percent. This need is based on current student aimed competencies, namely being able to use basic level GIS. However, the expected learning goal is to be able to analyze spatial data using GIS. Students of geography education are prepared to become geography teachers in schools that are qualified to teach GIS to students to develop GIS both in universities and in schools. Therefore, it is necessary to develop GIS learning, which materials are creative, innovative, fun, easy to understand and contain components of spatial thinking in the content, assignments, and evaluation sections.

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