Effectiveness of Using Geographic Information Systems (GIS) in Teaching Geography in Indonesian Schools

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ABSTRACT

A number of teachers in several countries around the world have used GIS for geography learning. However, the widespread use of GIS could be improved by, among other things, the limited availability of applications in the education sector. Based on these circumstances, this research aims to develop a Geographic Information System that is easy to use and has appropriate data availability for geographic learning purposes. The *quasi-experiment* design used in this research is a design with an unequal control group. Pretest and posttest were carried out to measure learning effects. We also compare learning supported by GIS as a learning medium with conventional learning in geography subjects. In this research, student learning effectiveness is measured through the level of understanding of the two main assessment components in geography learning: learning motivation and learning achievement. Nonparametric analysis was carried out to determine whether the increase was significant. The experimental results show that after learning with the support of GIS as teaching media, students' ability in learning achievement (average difference = 1.95 $p < 0.01$) increased significantly. The ability to learn motivation was also much better than the control group (mean difference = 3.07, $p < 0.05$). This shows that learning using GIS as a learning medium has positive results and supports student learning. GIS as a learning medium is also better than using traditional teaching with conventional learning in various measurable effects.

Keywords: learning media, quasi-experiment, learning achievement, learning motivation, geography learning, Geographic Information Systems

1. Introduction

Geography is one of the subjects in the school curriculum, both in Indonesia and other countries. This means that geography content is considered very important for students, not only in Indonesia but in various countries in the world [1]. Geography helps students understand their country and other countries in the world; geography is related to citizenship, economics, history, and the environment [2-3].

The various enormous benefits of geography have yet to be fully realized, considering that geography education in schools is still faced with a number of problems. Currently, geography lessons still need to be considered attractive [4]. According to him, several factors cause this, namely: (1) geography lessons are often caught up in the cognitive aspect, namely memorizing the names of places, rivers, and mountains, or other facts; (2) geography is often associated with science that only makes maps; (3) geography only describes human journeys on the surface of the earth; (4) the geographical science learning process tends to be verbal, does not involve facts, does not use concrete media and the latest technology; and (5) less applicable in solving currently developing problems. These conditions influence students' interest in studying geography. Results of research on 9 2 students show an unsatisfactory trend in students' interest in geography subjects [5]. Students are asked to rank the subjects they like. Geography subjects are ranked 6th out of 13 subjects at school. Only 5 students (5.2%) out of 97 students made geography their favorite subject.

Before improvements were made, things like this had actually happened in developed countries such as America and England. Geography education in England also tends to be repetitive and unfocused [6]. This condition will make the position of geography education in schools increasingly less taken into account. If a subject is considered boring and irrelevant by students and needs to be more critical by policymakers, then, in the end, the subject will retain its place in schools. [6-7].

Lack of student motivation to learn geography can occur due to a lack of use of media and teaching resources as well as varied and exciting methods. As a result, the value or benefits

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of geography education for life becomes a question. Results of a survey of 126 students at one of the tertiary institutions in Indonesia [8-9] show that 70% of their geography teachers in high school only used standard tools or media, namely maps. Only 15% use globes and other media, and the remaining 15% do not use props at all. All students also revealed that the method most often used by geography teachers when they were in high school was lecturing. The limited availability of learning media in schools is an essential factor in the need for more use of learning media in geography learning.

The limited variety of methods and use of learning media in schools will undoubtedly mean that geography learning activities need to run optimally. The continuous use of the lecture method makes geography lessons tend to be verbal and distance students from the natural world around them. In fact, one of the goals of learning geography is to make students have knowledge and understanding about the place where they live. It is essential to build primary depiction and spatial concepts by first using images of familiar environments in which children live and move, such as classrooms, school environments, and homes, before moving on to pictures of broader and more distant environments that are unfamiliar to them. [10-11].

Statement [10-11] emphasizes the importance of introducing the surrounding environment first before introducing the wider environment. The same thing was also conveyed by [12-14], which puts forward two principles of effective teaching, namely: first, students will learn better if they are exposed to the real world, thereby giving them the opportunity to develop critical concepts more substantially and completely; secondly, students can learn better if they deliberately build connections between subjects and contexts that are familiar or familiar to them.

Geography's subject matter offers knowledge about space with the various forms and processes that occur in it, both physical and socio-cultural [15-16]. Knowledge about multiple landscapes in different locations with various unique features and processes that occur in them is exciting to study. Something that is really needed by students who are interested in new information or things [17]. Unfortunately, this lesson is considered less attractive for many students.

The development of information and communication technology is an opportunity to improve the quality of geography learning [18-26]. Various types of information are available in huge quantities. Information and communication technology can also be used as a more exciting learning medium for students [27-31]. The problem is that until now, not all schools have been able to obtain optimal benefits from this development. As a result, the learning process could be more exciting and tend to be rote [32].

Therefore, it is not surprising that learning at school, especially geography is not interesting for students. Geography is only conveyed verbally, so students only imagine actual objects in the field. Therefore, it isn't easy to expect students to gain optimal benefits from geography lessons. It is not easy to gain benefits from studying Geography if there is no atmosphere of discussion and sharing of opinions for students; more emphasis is placed on memorization, and it is only descriptive. [33-35].

Based on this, it is necessary to innovate in geography learning. Learning methods that tend to be classical and have been widely used up to now must be combined with techniques that provide more space for students to develop their potential [9]. The teacher's role is to encourage and motivate students to seek and utilize various learning resources. Learning media, such as computers, can be used as a practical learning resource for students. In this regard, Geographic Information Systems (GIS) as a spatial-based information system can be

used as a learning medium and learning resource to recognize and understand geographical conditions or the environment around students. [35] .

Geographic Information Systems (GIS) have been developing since the 1960s and have made significant contributions in various fields of development. This spatial-based technology has been used in the fields of forestry, regional planning, mining, *real estate*, and others [36-38]. GIS can also be used in the educational sector [5]. Students can explore various spatial information in their area. Adequate database support allows students to find out more about the objects in the map display.

However, the benefits of using GIS for learning have yet to be widely developed in Indonesia. The GIS material in the curriculum tends to introduce GIS as an information technology so that there is more learning about GIS (*learning about GIS*) instead of teaching using GIS (*Teaching with GIS)*. [39-41]. GIS material is in class. In fact, GIS has excellent potential to help increase students' understanding and learning motivation [42-44].

Research on the use of GIS in education also still needs to be explored. There needs to be more research that examines GIS-based learning as a means by which students can access or interact with geographic information, develop their learning approaches, encourage learning activities between subjects, and create and interpret various representations of geographic information [45-47].

What is conveyed by [45] is also similar to what is conveyed by [48], who stated that the geography education research community still needs to gain confidence regarding the certainty of GIS's substantive contribution to learning. They also cannot firmly state that GIS has a positive effect in developing the ability to think and analyze spatially as the primary goal in geography education.

Apart from research, which is still scarce, the availability of software On the market that is specifically applied in education is still rare, especially GIS software, which contains a database that is appropriate to local conditions. Based on research results [49], apart from insufficient time to apply GIS, the material in the GIS database is not in accordance with the objectives of the curriculum, and GIS software is considered complicated. The teachers hope that there will be some GIS-based learning kit that is more *user-friendly so that it is ready for teachers to use* more efficiently [50].

Based on this, it is necessary to develop GIS applications for Geography learning and research the influence of GIS applications as a learning medium on students' motivation and learning achievement. In this way, students are expected to be more motivated to learn geography, and there will be no more students who do not know the local conditions of their area. Apart from that, of course, in the end, it is hoped that their learning achievements in geography subjects will also get better. We cover the following critical issues in this article:

1. Developing GIS applications as a Geography learning tool in Senior High Schools?
2. Comparing learning supported by the use of GIS as a learning medium with conventional learning on students' learning motivation and learning achievement in geography subjects?

This article is organized as follows: In Part. 2, GIS technology and its application in the field of education and learning. In part 3, we explain the latest GIS technologies and how they can be used to support education and learning. Part. 4, we describe the Experimental results, including participant background and results, in Sect. 5, proposed GIS teaching approach, and Sect. 6, contains conclusions.

2. Literature Study

2.1 GIS technologies

Different terms know GIS but with the same meaning. In the United States, the term used is *Geographic Information System*. Almost the same as America, in Europe, it is known as *the Geographical Information System*.

A number of experts have put forward various limitations regarding GIS. GIS is a tool capable of processing spatial data into information, generally information that is explicitly related to and used to make decisions about a particular part of the earth. [51] . De Mers' opinion shows that GIS processes spatial data into spatial information for decision-making. This information is new information resulting from data processing and analysis.

It is defined as an information system designed to work with data that has geographic or spatial coordinate references. GIS is a database system with unique capabilities for handling data that has a spatial reference and also a set of operations for working with data. In other terms, according to him, GIS is seen as a map in a higher position [52-54].

Based on several definitions from these experts, three keywords make them the same as each other, namely computer system, information system, and spatial reference. The benefits of utilizing GIS are many related to technical applications, such as efficiency in data handling, improved analytical and cartographic capabilities, increasingly attractive visualization and communication, and decision-making. [55] .

2.2 Use of GIS in the Education Sector

In the field of education, GIS has been used by policymakers to plan and manage education. GIS can also be used in research and learning activities, especially in geography subjects. In the educational field, GIS can be applied to manage campus infrastructure, including security, buildings, telecommunications, registration, recruitment, and alumni networks. [56] . According to him, people are interested in GIS technology and methods to the extent that the question "where" is essential in research.

A number of experts then developed GIS for learning purposes. GIS is not only able to visualize spatial-based data but is able to support learning that is centered on student activities. This role can not only support geography learning but also other subjects. GIS can be applied to many educational disciplines, such as biology education, history education, and economics education [49]. However, according to him, the main application field is Geography Education.

The use of GIS for learning purposes is based on a number of reasons. There are a number of reasons why GIS is important to develop in schools [57]. These reasons are (1) educational considerations, GIS and its theoretical superstructure (*GIScience*) support geography learning; (2) workplace considerations, GIS is a fundamental tool for 21st-century workers; and (3) location-based considerations, GIS is an ideal tool used to assess the environment in a local community or environment. Another reason is spatial reasons because GIS can evaluate certain areas [58]. Apart from that, it also provides an atmosphere where students can learn by doing it.

[59] stated the reasons why GIS has excellent potential to be applied in the field of education. According to him, GIS's ability to display geographical, scientific, social, political, and economic data, as well as various other types of data visually and from different points of view, can create substantial learning opportunities for teachers and students. The results of his research show that the use of GIS helps students build concepts and increase their

understanding of the environment, problem-solving, experimental design, and data analysis, as well as communicating findings to others. The use of GIS in classroom learning is a way to incorporate spatial learning in schools.

[48] stated the rational reasons behind the inclusion of GIS into education, namely 1) GIS is a vital tool for analyzing and solving environmental problems, especially for the local scope 2) GIS can increase interest in geography and related subjects 3) GIS is an attractive technology to motivate students to pursue careers in the fields of *science* and *engineering*. According to him, the inclusion of GIS into geography education meets the demands of the world of work and allows for a smooth transition between school and work.

The vital reason for including GIS in learning activities must be distinct from the benefits it offers. [56] stated the advantages of using GIS in learning, namely helping to develop thinking skills, the ability to analyze data, the ability to solve problems, and the ability to access geographic data easily and develop geographic curiosity. According to him, when using GIS, students learn about the earth, its processes, its inhabitants, and how the world changes from natural and human influences. They also have skills that can be used in the future when working as regional planners, epidemiologists, soil scientists, climatologists, cartographers, lawyers, biologists, geographers, economists, and other fields of work. Furthermore, according to him, GIS can be seen as a tool that helps students to develop thinking skills, the ability to analyze available data, the ability to solve problems, the ability to access geographic data more efficiently as well as geographic curiosity.

At the school level, GIS has many benefits to be developed as a learning resource and medium. GIS allows more interaction than atlases, which have several limitations, especially in data and map analysis. GIS will enable students to access any information they see at various levels/scales according to their wishes [33].

GIS is used as a tool to support Problem *-Based Learning*. [60] . This learning model allows students to examine the local environment in different ways. This model uses an inquiry approach, which gives students the opportunity to build their data and obtain this data from the local environment, both around where they live and around their school environment. This is also important in relation to contextual learning.

Although there are a number of advantages to using GIS in education, [61] stated that the use of GIS in schools still needs to be expanded and varied. The same thing was also noted by [62], saying that integration and appropriate didactic description are still in their infancy and progress is slow. Similar findings were also presented by [63], who stated that since 1990, GIS has become an essential part of everyday life, but its significance in schools is still weak. GIS has experienced slow diffusion into secondary schools and teacher education [48]. According to him, although GIS is an integral part of geography, it is rarely used as a teaching technology. Teaching about GIS (*instruction about GIS*) is more developed and more attentive than teaching using GIS (*instruction with GIS)*. The entry of GIS in the education sector can be identified in three forms. First, GIS is one of the subjects of discussion; of course, the emphasis is on teaching or learning about GIS (Teaching *or learning about GIS); second*, using GIS for learning *(learning with GIS)*; third, using GIS to teach (*teaching with GIS)* [56].

2.3 The Influence of GIS on Achievement and Motivation in Learning Geography

GIS, as explained by its ability to analyze and display spatial data, has the potential to increase student achievement and learning motivation. The ability to combine spatial data

and display spatial data in various formats, such as maps, text, tables, videos, or films, can reduce verbalism in geography learning.

However, the results of a number of studies on the effects of GIS on learning still need to be consistent. A number of research results show the positive contribution of GIS-based learning. The results of the study conducted by [5] showed a statistically significant positive contribution in the experimental group. The scores in the experimental group far exceeded the scores in the control group. Both stated that the benefits of GIS in learning geography are not only felt by students who are strong in their computer skills but also by students who are weak in their computer skills.

Studies conducted [33] show that teaching geography assisted by GIS provides benefits for students in the form of a better understanding of the material taught and makes it easier to access scientific data that is appropriate to the material being studied. In the case of population migration, which he studied, [33] stated the advantages of constructivist teaching methods assisted by using GIS, namely, developing geographical skills and the ability to use inquiry methods, can combine the results of the studies they make with experience when carrying out the inquiry process, can increase geographical knowledge and can build connections between aspects of physical and human geography [64] researched the effects of GIS on academic achievement and learning motivation in Turkey. The results showed that there was a significant difference in test scores between the experimental group and the control group. The experimental group that used GIS-based learning showed higher scores than the control group that used traditional learning. Apart from that, learning motivation in the experimental group was also statistically higher than learning motivation in the control group.

The actual effect of GIS on geography learning has yet to be discovered. The results of research conducted by a number of researchers are still inconsistent. Some researchers show a positive effect of GIS on geography learning, but others do not show a positive impact. The environmental and geography education research community needs to know for sure the contribution of GIS to geography and ecological learning [48]. Furthermore, he also said that several recent studies make it clear that more is needed to know about the real benefits and learning outcomes of GIS. Therefore, it is difficult to state unequivocally that GIS at primary and secondary education levels has a clear and positive effect on the development of spatial thinking, spatial *reasoning*, and environmental understanding as the central goals of geography learning.

3. Method

This research was designed to develop geography learning media and conduct experimental trials. This development is based on the need for spatial-based learning media with various data formats (multimedia) and using local databases to support contextual learning. For this purpose, a Geographic Information System (GIS) has been developed that is easy to operate and capable of displaying data in various formats. The user interface design is intended to be straightforward, with basic facilities for displaying thematic maps, browsing data, displaying data in multiple formats, and carrying out basic commands. This research uses an experimental design to examine whether using GIS affects geography learning. Experimental methods can be divided into accurate experimental methods *(actual experiments*) and quasi-experiments (*quasi-experiments*). The quasi-experimental design used in this research is a design with an unequal control group. In this research, student learning

effectiveness is measured through the level of understanding of the two main assessment components in geography learning: learning motivation and learning achievement.

3.1 GIS Application System

system development is carried out by determining appropriate GIS applications to support learning activities. Several considerations are used when choosing the application to be used. One important consideration is that the application used is a free or open source application, so *that* the data is used freely. One of the free and *open-source applications* for building desktop GIS is DotSpatial. DotSpatial is a Geographic Information System *library* written for .NET 4. DotSpatial provides programmers with the ability to combine spatial data, analysis, and mapping capabilities into their applications. DotSpatial has the following capabilities.

1. Displays the map as a .NET window or Web application
2. Opens shapefiles, GIS, rasters and images
3. Displays labels and symbols
4. Manipulate and display attribute data
5. Conduct scientific analysis
6. Reading Global Positioning System (GPS)

Microsoft developed the .NET framework software, which is widely used by software applications that use *the Windows platform*. The .NET software framework enables *interoperability* across programming languages. It contains the CLR (*Common Language Runtime*) and *class library*. The CLR provides a software environment for executing programs written for .NET [65]. DotSpatial has been used for a variety of desktop GIS applications outside of the educational field. Apart from being relatively new, most GIS applications in the education sector use existing GIS applications or customize *the interface* design according to needs. Development is mostly only carried out by providing a database according to the topic being studied. Therefore, developing a free and *open-source application* is interesting to do.

In building a GIS Desktop, it is necessary to design an *interface architecture* and its functions that suit your needs. Therefore, the first step in building a GIS Desktop with DotSpatial is identifying the need for executable functions. These needs are:

1. functions to perform standard operations (zoom in and out of the map, shift the map, display attribute data information)
2. function to display spatial data in the form of thematic maps
3. function to display data in the form of video or animation
4. function to perform *queries* from data that has been built

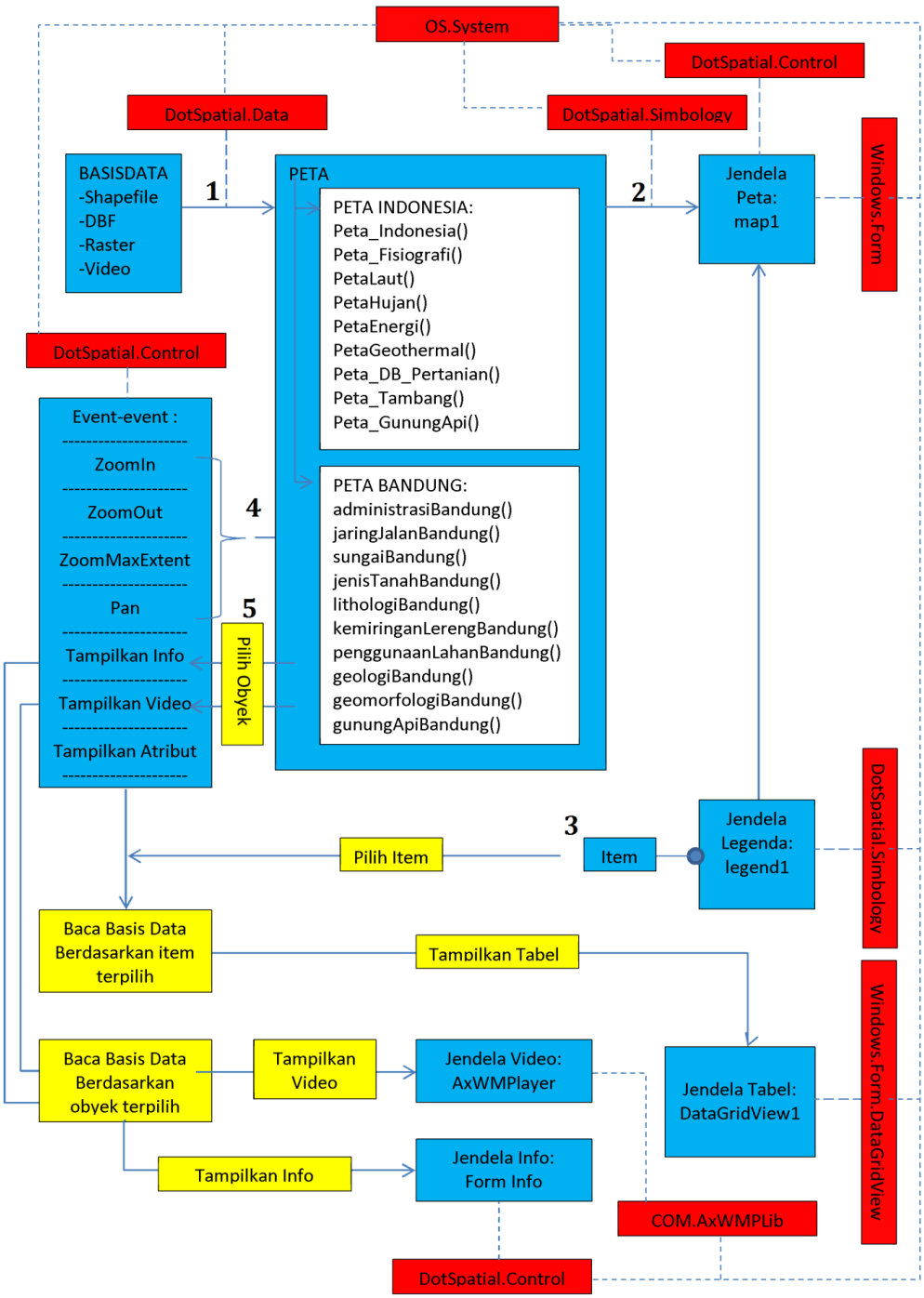
Based on the need for these functions, an application flow concept will be built, consisting of an opening system superstructure, application object entities, and application process flow objects. **Picture. 1** shows a diagram composed of the Library System superstructure (depicted in red boxes), Application Object Entities (depicted in blue boxes), and Application Process Flow Objects (shown in yellow boxes).

All objects in the blue box are derived from the red box library system, except for stand-alone databases. These objects are Map, Map Window, Event, Legend Window and its items, Table Window, Video Window, and Info Window.

The main principle in the relationship between object entities and processes is that each object entity requires input from the database and is output to become input for other

entities, either by direct methods or derivative methods. In this case, the process object plays a role in the relationship.

The relationship between the Database and the Map Class is *many to many*. Each shapefile database can be a member of any existing map class. The relationship between the map class and the map window is *many to one*, where there is only one map window that populates the Map class to be managed. The relationship between the Map Window and the Legend Window is *one-to-one*, where each *shapefile object* in the map window is related to one map legend item.



Picture . 1 D diagram consisting of library system superstructure

The relationship between video windows and info windows with the database is *one-to-one* because only one object can be selected, and only one unique unit of info and video can be displayed in these windows. The processes running in the application are explained as follows:

Process 1 The database is initialized with the DotSpatial library. Data is arranged in Map classes. The Map class is written as a function with the syntax Map_CertainThemes(). This process initiates the projection system, the types of data types, and how to represent them.

Process 2: The Map classes, after being initiated, are determined by the way the DotSpatial presents them.Symbology library. This library reads the results of type initiation and sets the data symbolization in the Map Window.

Process 3: The Legend Window obtains information or references the Map Window. Each Map class object displayed in the Map Window will be populated in the Legend Window as an item. These items are processed or subjected to special events such as displaying attributes. Items selected in the Legend Window will be managed by special Events such as opening the attribute table. Selected item information is used to populate the database chosen based on those items. Then, the event will be displayed in the Table Window, which is a derivative of Windows.Form.DataGridView.

Process 4:Map Window is a derivative of the Windows. Form, and DotSpatial.Control libraries. It is in the map window that standard events such as *zoom in*, *zoom out*, *zoom extent*, and pan work on Map classes. The event is also an instance of DotSpatial.Control.

Process 5: Special events, such as Show Info and Show Video, will select particular feature objects from the Map class displayed in the Map Window. This special event will be chosen based on the uniqueness of the data, which is then searched and adjusted to the database. The information is populated based on the selected feature object and then sent to the Info Window for the Show Info event. The Show video event will search for video data based on information data from the selected feature. If a video is found, it will be displayed in the Video Window.

3.2 Development of GIS applications and case scenarios

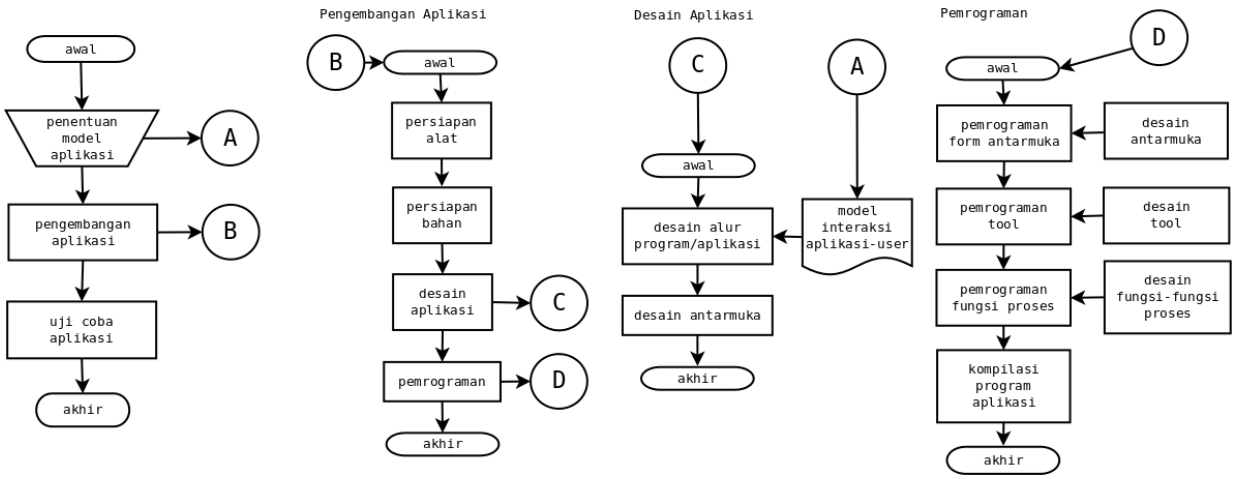
This research was designed to develop geography learning media and conduct experimental trials. This development is based on the need for spatial-based learning media with various data formats (multimedia) and using local databases to support contextual learning. Materials or materials developed using GIS refer to the independent curriculum. This was done because at the time the research was carried out, the implementation of the independent curriculum had already been implemented, including at the school where this research was carried out. The materials chosen are material about the potential of natural resources in Indonesia in class. The interface design (user interface) was carried out because the existing GIS application was intended to be something other than a learning medium. Interface design planning Strives to be simple, consisting of main menus and windows that are really needed. The selection of menus and windows is designed taking into account the ease of obtaining and displaying geographic data. The four main capabilities selected are:

1. Ability to display thematic maps according to the material in the curriculum.

2. Ability to perform data searches (*data queries*) according to the needs of users or students in relation to learning activities.
3. Ability to display data in several formats, namely maps, tables, text, and video.
4. Ability to perform basic commands such as *zoom in*, *zoom out*, info, pan the map, and others.

These various capabilities become materials in developing interface designs GIS. Based on the main capabilities to be developed, *a physical computational model is then carried out*, *which explains how the software is developed*, *how the processes occur with the data*, and how the data is organized in a particular device. The application preparation was carried out using Microsoft Visual C# Express. Implementation includes two things: the first is arranging the Windows interface, and the second is compiling the code. **Picture. 2** shows the application development flow.

Picture . 2 Application Development **Flow**



Based on the application process flow, *the Graphical User Interface* (GUI) is built using these flow considerations. Thus, the interface design allows users to perform *queries* to display maps, videos, and attribute data so that the available windows are in the form of a map window, selected layer, video/film, info, and a window for displaying attribute data. The results of the interface design development can be seen **in Picture. 3** following.

Picture. 3 Digital contents displayed on the recognized teaching material

Information:
1: Window to display the map
2. Window to display the selected layer
3. Window for displaying attribute data
4. Window to display info
5. Window for displaying video

To support geography learning, the GUI and documents are adapted to the topic being studied, namely the potential of natural resources in Indonesia in class X I Phase F. In the picture, you can see several menus displayed, namely Menu, Operations, Indonesian Map, Bandung Map, and About Application. Apart from that, there is *a toolbar* for the functions of enlarging the map and reducing the map, returning to the initial position, displaying information, and showing videos. Students can explore the data provided in GIS to determine provinces producing certain commodities. The data displayed is in the form of graphical data and attributes. Students can see the distribution on the map and in the attribute data.

3.3 Research procedures

The developed application is then tested using experiments. An experiment is research in which variables are manipulated, and their effects on other variables are observed [66]. Experimental research is the only research that directly influences certain variables and is the best type for testing hypotheses about cause-and-effect relationships. [67] . According to him, the main characteristic of experimental research that differentiates it from other research is that the researcher manipulates the independent variable or treatment variable. Meanwhile, [68] suggests that experimental research is an experimental design with each action step defined so that information related to or needed for the problem being researched can be collected factually. Experimental methods can be divided into accurate experimental methods *(actual experiments*) and quasi-experiments (*quasi-experiments*). The experimental procedure used in this research is *quasi-experiment*. Quasi-experimental designs do not include the use of random *assignment*. [69] . Quasi-experimental studies have advantages over accurate experimental studies, especially for behavioral and social research [70]. Human behavior is complex, so that many factors can influence behavior.

The quasi-experimental design used in this research is a design with an unequal control group. This design does not involve random assignment to select groups of subjects, as is done with actual experiments. The existing groups were chosen as experimental and control groups. For both groups, initial measurements or pre-tests were carried out. Next, the experimental group was given treatment by implementing learning activities using GIS media as a learning medium. The control group implemented conventional learning activities without using GIS as a learning medium. After that, both were measured using a post-test. After that, measurements were carried out using a posttest, both in the experimental group and the control group. The students were invited to participate in the study voluntarily and were randomly divided into two groups. We measure students' abilities in geography learning based on two main assessment components in geography learning: learning motivation and learning achievement.

Both groups of students were required to take a pretest first to measure their abilities regarding a certain level of understanding in learning geography. Visual material about

Indonesia's geographical potential is used as a case study to prepare questions in the pretest. Students are asked to answer questions related to Indonesia's geographic potential. Then, students study the material with assigned learning support. For the experimental group, a 15-20 minute briefing and introduction session was given on the operation of the GIS application to understand its operation. This ensures that students can focus on learning during the test without being distracted while operating the GIS application. The posttest begins after students are familiarized with the basic operations of GIS applications. Both groups of students were allowed to study the material about the potential of natural resources in Indonesia and understood it for 15 minutes with predetermined learning support. Right after the learning session, a posttest with the same test type and difficulty is used to assess students' abilities, as in the pretest. Students are asked to answer questions related to material about the potential of natural resources in Indonesia in the posttest. The questions in the test are prepared based on the teachers' experiences. Preliminary practice is also carried out to measure the level of difficulty and duration of the test. We decided to use 40 questions for both tests, with 1 minute for each question to measure learning achievement and 60 questions to measure learning motivation. The test consists of multiple-choice and open-ended questions.

3.4 Data analysis

Statistical analysis IBM SPSS 23 was used for statistical analysis in this study. Nonparametric tests were adopted to investigate the performance of the same target group of students. Although student performance is measured based on test scores, assessment schemes are still differentiated based on the qualitative nature of questions used in the tests and limited sample sizes. The Wilcoxon signed-rank test was adopted to compare the pretest and posttest differences after learning with GIS. To investigate the students' background and their abilities, the Mann-Whitney test was adopted to compare the experimental group and the control group. A p-value <0.05 was considered statistically significant.

4. Results

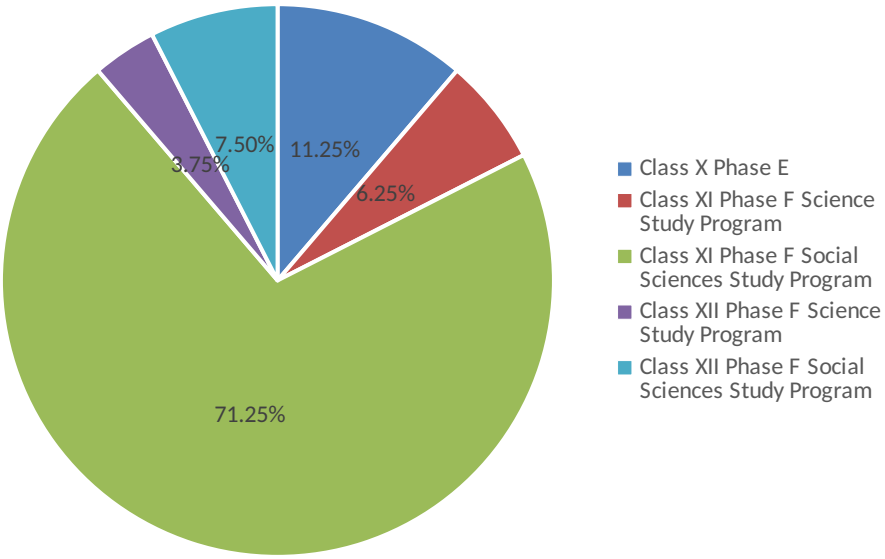
This research was conducted at a high school in Indonesia. A sample of N = 80 students participated in this study voluntarily. The students were divided randomly into two groups, where Nt = 41 (51.2%) students studied with GIS support as a learning medium (experimental group), and Nc = 39 (48.8%) students studied with traditional materials (control group).

Table. 1 Participant characteristics and educational background

Variable	Experimental Group	Control Group
Mean age (years ± SD)	17.56 ± 2.17	17.67 ± 1.36
Man	23 (56.1%)	20 (51.3%)
Woman	18 (43.9%)	19 (48.7%)
1 – 3 Years of High School Education	41 (100%)	39 (100 %)
Studying geography lessons	36 (87.8%)	36 (92.3%)
Not or have not studied geography lessons	5 (12.2%)	3 (7.7%)

Table . 1 summarizes participants' characteristics and educational background. The sample mainly consisted of men (53.75%) in both groups, with an average age of 17.6 years (SD = 1.87), where most of the students had previously studied geography subjects. **Picture. 4** shows the distribution of education levels based on each student's class. It is known that most of the participants are in class XI Phase F of the social science education program.

Picture. 4 The educational level of the participants is in high school



Considering the differences in knowledge in the design subject between the experimental group and the control group, the Mann-Whitney test was conducted to investigate students' abilities in two main assessment components: learning motivation and learning achievement.

Table. 2 Student material knowledge between the experimental group and the control group

Measures	Experiment group *N* = 41 Mean score (SD)	Control group *N* = 39 Mean score (SD)	*Z*	*p* value
Motivation to learn	7.26 (7.73)	6.17 (6.31)	-0.361	0.641
Learning achievement	2.25 (4.35)	1.86 (3.74)	-0.375	0.753

(*Z*) *Z*-score; (*p*) significance level Students' design abilities by studying with the support of the GIS

Table. 2 shows that although the experimental group scored higher in students' learning motivation (mean difference = 0.612, p=0.641) and learning achievement (mean difference=0.47, p = 0.753), the p-value> 0.05, which means there are no significant differences in student background and abilities between the experimental group and the test group. Once students learn with the assigned learning support, they are asked to complete a posttest. The Wilcoxon signed rank test was carried out to determine whether there was an improvement in studying geography with the support of GIS. A positive

difference indicates that the average value of the experimental group is higher than the control group.

Table. 3 Level of significance of students' learning abilities with GIS support

Measures	Mean difference	*Z*	*p* value
Motivation to learn	0.00	-0.017	0.983
Learning achievement	1.95	-2,257	0.03**

(*Z*) *Z* -score; (*p*) significance level
(*) $p < 0.05$; (**) $p < 0.01$

Table. 3 summarizes the students' abilities between the experimental group and the control group; it was found that learning achievement (average difference = 1.95, p = 0.03) increased significantly. The experimental group and control group were compared to determine whether there were significant differences in ability on the assessment components. The Mann-Whitney test was applied to investigate the differences.

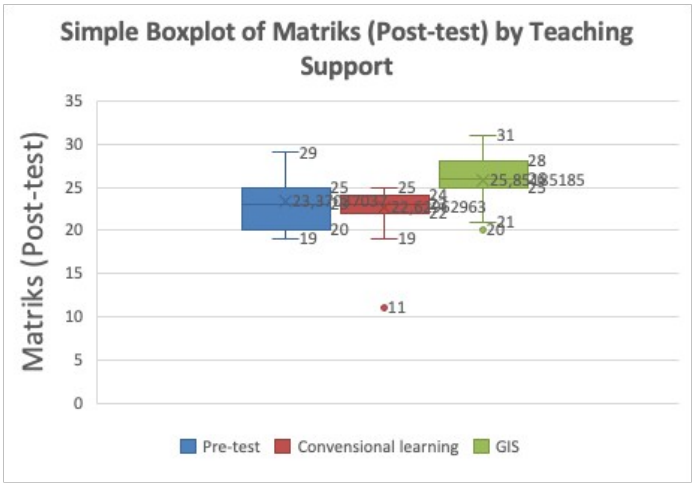
Table. 4 Student abilities between the experimental group and the control group

Measures	Mean difference	*Z*	*p* value
Motivation to learn	3.07	-2,073	0.036*
Learning achievement	0.814	-0.644	0.542

(*Z*) *Z* -score; (*p*) significance level
(*) $p < 0.05$

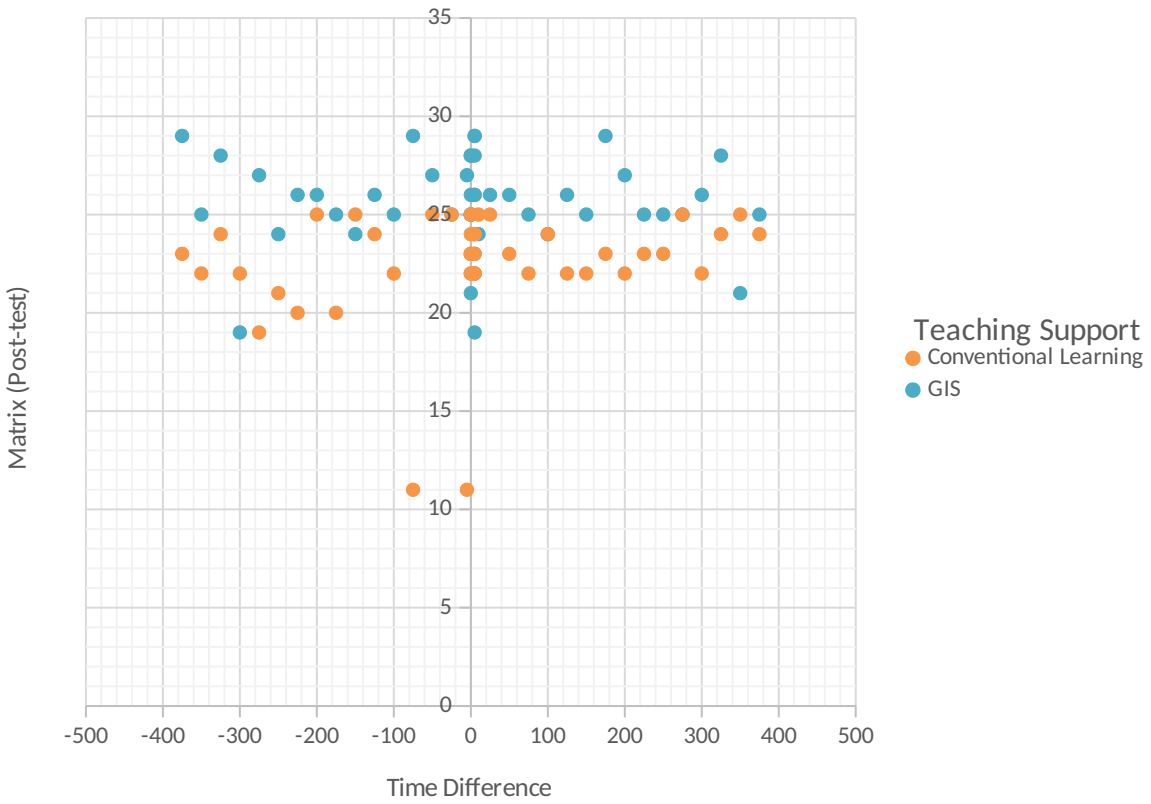
Results in Table. 4 shows that the experimental group scored higher on all measures. However, the performance of the experimental group was significantly better than that of the control group, with only differences in students' learning motivation (mean difference = 3.07, p = 0.036). Finally, we compared students' overall test performance with learning supported by the use of GIS as a learning medium with conventional learning on the posttest.

Picture. 5 A boxplot of students’ overall test performance studied with the support of the GIS and conventional learning in the posttest. Their performance was compared with that of the students in the pretest.



Box plots (**Fig. 5**) were used to compare their scores in the pretest. Their performance was also compared with the student's performance on the pretest. Students' overall performance is calculated based on the total score of their measured design abilities. It was found that there were several outliers in the pretest group, and students studied with conventional learning without using GIS as a learning medium. Although their medians were the same, the pretest group showed more significant variability in scores compared to students who studied with notes and conventional learning. This implies that students have more consistent performance after learning with traditional learning without using GIS as a learning medium. Still, the improvement is not significant, while students who learn with GIS show a general increase in their overall performance.

Picture. 6 Scatter plot of each student's overall performance performed in the posttest against the time difference to complete pre- and posttests



By removing outliers from the data, **Fig. 6** illustrates each student's overall performance in the posttest against time to complete the test in a scatter plot. In this picture, the x-axis represents the student's overall performance in the posttest, and the y-axis refers to the time difference between the students completing the pretest and the posttest. A positive number means students spent less time completing the posttest, so they experienced improvement, while a negative number means students spent longer completing the posttest. It was found that most students (56.1%) spent the same or less time completing the posttest, of which 61.3% were students who studied with GIS (blue dots). On the other hand, their overall scores were generally higher than those of students who studied with traditional notes (blue dots). Although some students took longer to complete the post-test, their performance was usually higher than students who studied with conventional notes.

5. Discussion

Our research investigates students' abilities in geography learning in high school education with the support of GIS technology. Students are invited to participate in the study on a voluntary basis. Judging from the participants' backgrounds, most of the participants had studied geography subjects before. Students who did not research geography from the experimental group and control group were 12.2% and 7.7%, respectively. It is recommended that students who do not have a strong geography background remain interested in studying with GIS, especially for class XI Phase F students in the social

education science program (71%), class X Phase E students (11.25%), and class XII Phase F social education science program (7.5%). Most of the participants were male (53.75%).

The pretest was carried out to determine students' background in the field of geography. It showed that students' ability in learning motivation was the highest (average score = 7.53) compared to learning achievement (average score = 2.86). This may be due to the very conceptual theory in learning geography and training student motivation and achievement at school. Therefore, further training and practice in these aspects should be considered. On the other hand, this means that there is no significant difference in measured abilities between the experimental group and the control group based on the participant's background at the start of the test being similar.

After students learned to use GIS as a learning medium, their ability in learning achievement increased significantly ($p < 0.05$). This is in accordance with what was stated by several researchers such as [33], [58], [71]. The learning achievement of students in the experimental group was significantly different from the learning achievement in the control group. Geography learning achievement was higher in the experimental group than in the control group. This result can be understood because students search for information themselves, so they don't just get information cursorily but look for it themselves. The results of these searches will continue to be remembered by students for a longer time than just listening to them in passing. However, only students' learning motivation abilities were significantly better than the control group ($p < 0.05$). This is in accordance with what was stated by [72], which indicated that the use of media plays a vital role in students' learning motivation. Likewise, [72] noted that the use of media technology such as computers motivates students to learn various lessons effectively by making them want to know in their way and challenging them to look for information on computers and the internet whenever they are free. [73] I also concluded the same thing, namely that effective integration of technology in learning has an impact on students' motivation, encouragement, and interest in learning. Technology integration can increase learning motivation.

Students have a greater interest in learning activities that use technology compared to traditional approaches because students are intrinsically motivated to use computers. The results show that the material about the potential of natural resources in Indonesia is more complex for the majority of upper secondary education students than the material about Indonesia's geographical potential. Learning Conventional methods without using GIS as a learning medium are not adequate for helping students visualize material. GIS is still an effective means for students to visualize material models spatially compared to conventional learning using traditional teaching materials. Although the increase in learning motivation was not significant in the experimental group, both measured abilities increased with the support of teaching materials. On the other hand, overall student performance improved compared to the control group. Most students (61.3%) who studied using GIS as a learning medium spent the same or less time completing the posttest, and their overall performance was also generally higher than the control group. It is recommended that students' geographical analysis abilities and creativity can be improved. Therefore, more support is still needed for students in schools.

GIS as multimedia needs to pay attention to factors that influence its effectiveness in learning. Effective learning media, especially multimedia, according to [74], is influenced by design factors and individual characteristics. Design factors consist of layout design, attractiveness, and multimedia quality. Multimedia must have a layout design that meets

the principles of good layout. These principles are that images and text must be close together (*spatial contiguity principle*), messages and pictures must be simultaneous (temporal *contiguity principle*), inappropriate material must be discarded (*coherence principle*), for animation, it is better to use sound rather than writing (*modality principle*) when using animation and audio, the use of text is not necessary (*redundancy principle).*
Multimedia must be enjoyable because the processing capacity of the human brain is limited, so humans will carry out a filtering process on the images or messages they see. Therefore, the media must be engaging so that it becomes the focus of human attention. Attractiveness can be seen in voice intonation, image, speed of voice, and so on.
Multimedia quality refers to the physical specifications of the information displayed. Examples are image resolution and the number of colors used. The higher the resolution and number of colors, the better the quality.
The lack of influence of GIS as a medium and learning resource on learning motivation can also refer to the opinion expressed by [75]. According to him, several things need to be considered in achieving effective use of media or, in this case, technology. Namely, teachers must be sufficiently trained, have careful planning, have easy access, and be positioned only as an effort to increase learning motivation.
Other reasons can also refer to the opinion [76-78]. The results of the analysis show that it is not the technology used or not used that makes the difference but how well the technology is used to support learning. The benefits of using technology will only be obtained if the activity is effectively integrated with what is to be learned or if pedagogical aspects are taken into account. The same thing was also conveyed by [79], who believes that method and medium should have a more integral relationship. Both are part of instructional design.
Based on this description, learning media does not always influence learning motivation. Several things need to be studied further regarding how well the learning media or GIS applications are developed and how appropriate the methods used are. This research also produced findings regarding the effectiveness of GIS learning media on learning achievement and learning motivation.

6. Conclusion

Currently, GIS technology has high potential and plays an important role, especially in the field of education. The latest GIS technology has been proven to be effective in improving learning achievement, learning motivation, learning attitudes, and student effectiveness at the secondary school level. However, the evidence for measuring the effectiveness of learning is still preliminary. Geography is one of the subjects at the high school level. This can be characterized by the ability to balance creativity and a systematic approach that uses problem-solving and decision-making. In this article, we develop GIS as a geography learning medium, which is created in this research as a development of the DotSpatial *library*. The library is still a programming language, and the interface design is developed according to needs. We also investigated students' learning experiences in creativity and systematic approaches to learning geography with GIS, compared with conventional learning without using GIS as a learning medium. The GIS application developed has four main capabilities selected, namely: first, the ability to display thematic maps in accordance with the material in the curriculum. Second, the ability to perform data searches (*data queries*) according to the needs of users or students in relation to learning activities. Third, the ability to display data in several formats, namely maps, tables, text, and video. Fourth, the ability to carry out basic commands such as *zoom in*, *zoom out*, info, move the map, and so on. Material about

natural resource potential in Indonesia is used as a case study. The experimental results showed that with the support of GIS as a learning medium, students' ability to achieve learning increased significantly and was better than the control group in terms of learning motivation ability. This shows that learning using GIS as a learning medium has positive results by supporting student learning. GIS as a learning medium is also better than conventional learning in various measurable effects.

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