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Effect of The Spatial Based Learning Using Quantum Geographic Information System on Students' Critical Thinking Skills

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Abstract

The Spatial-Based Learning (SBL) model, developed in 2018, has evolved through the application of various spatial techniques. Its 21st-century emergence prompts an analysis of its impact on critical thinking. This study aims to examine SBL's impact using Quantum Geographic Information System (SBL-QGIS) on undergraduates' critical thinking. Conducted in the Geography Study Program at the Faculty of Social Affairs, State University of Malang, during the 2023–2024 academic year, it used a controlled experimental design. Pre-tests and post-tests were administered, with 120 students divided into experimental and control groups. Critical thinking was measured by evaluating formulating problems, providing arguments, drawing conclusions, proposing alternatives, and making decisions. The study findings reveal significant improvement in critical thinking skills due to SBL-QGIS, highlighting its potential in geography education to foster critical thinking. These findings can provide empirical evidence regarding the effectiveness of SBL-QGIS as an innovative learning method. Practically, these findings can serve as a basis for encouraging the development of more technology-based and interactive curricula and teaching strategies, as well as motivating more educational institutions to integrate similar technologies into their teaching. Academically, these findings can support further research that explores the impact of SBL-QGIS on various other aspects of learning, such as problem-solving skills, creativity, and collaboration. Additionally, these findings are useful for policymakers in formulating educational policies that support the integration of technology in the learning process, especially in developing students' critical thinking skills.

Keywords: *Critical Thinking Skills, Quantum GIS, Spatial Based Learning*

Introduction

The roles of geography learning have been examined collaboratively by geographic associations worldwide. Findings highlight that geography education goes beyond memorizing facts (Heffron, 2012; National Research Council, 2006). Geography teachers are vital in enhancing student

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engagement and knowledge acquisition. Effective geography education relies on active student participation, encouraging the use of skills such as map reading, posing geographic questions, and data interpretation (Harshman, 2015; Carrera et al., 2017). A key concern in geography education is offering experiential learning opportunities beyond the-e classroom, as noted by scholars such as Auer (2008) and Black, (2013). Hands-on experiences help students recognize geographical features and spatial patterns in their surroundings, fostering an appreciation for both local and broader geographic contexts (Kastens & Liben, 2010; Mkhize, 2023a; 2023b).

Learning of geography in Indonesia is currently facing several essential challenges. These problems include:(1) unequal access to technology and resources, (2) varying teaching quality, (3) less interactive learning approaches, (4) lack of contextual learning, and (5) difficulty in implementing outdoor learning (Soekamto & Handoyo, 2022). By addressing these issues, geography education can become more effective and engaging, helping students develop a deeper understanding of the world around them. Likewise in critical thinking, many studies test the effectiveness of learning strategies on students' critical thinking. Sari et al. (2017) demonstrates that Problem-Based Learning positively influences critical thinking and environmental attitudes. Sularmi et al. (2018) found that Project-Based Learning affects critical thinking. Ilmi et al. (2022) showed that Discovery Learning enhances critical thinking skills. Nurani et al., (2024) indicated that Geo-Inquiry also influences critical thinking skills. These findings highlight that various learning strategies have been employed to study critical thinking in geography learning. However, amidst these learning dynamics, research developing the use of spatial-based learning strategies with geospatial technology as a determining factor for critical thinking has not developed optimally. As a result, students are less competent in spatial analysis and critical thinking when examining geographic phenomena. For example, students are less skilled in creating thematic maps, mapping changes in land use over time, and conducting local environmental surveys to understand the impact of urbanization on ecosystems.

Efforts to develop spatial learning strategies in geography education date back to the 1980s. Initially, Breuker (1984), Goetz (1984), and Holley & Dansereau (1984) proposed a six-step approach involving selecting key concepts, writing them down, listing attributes, arranging them spatially, rearranging the representation, and comparing it with textual information. Subsequently, Siler (1998) introduced two types of spatial learning strategies: the classroom floor model and the pulp model, both used to comprehend historical events such as the Japanese occupation of the

American West Coast during World War II. Further advancements were made by Gersmehl (2014), who delineated a three-step process consisting of teaching location, circumstances, and linkages; describing location conditions; and identifying relationships with other locations.

The fundamental concept of spatial learning involves engaging students in spatial thinking (Gersmehl & Gersmehl, 2007; Golledge, 2002; National Research Council, 2006; Ridha et al., 2019). The underlying principle of this approach is to understand phenomena occurring on the Earth's surface (Heffron, 2012). It aims to address specific phenomena by examining their occurrence, location, processes, impacts on humans, and human interactions with these phenomena (Gersmehl, 2014).

The most recent advancement in spatial learning, pioneered by Handoyo and Purwanto (2017), is termed Spatial Based Learning (SBL). There are several reasons for developing this spatial learning model. *First*, there is a current need to strengthen students' ability to build knowledge spatially. Geography, the study of spatial phenomena, seeks to answer questions such as: What phenomenon is occurring? Where does this phenomenon occur? Why does it occur at that location? How has it evolved over time? Spatial-Based Learning (SBL) facilitates students in constructing spatial knowledge. *Second,* there is a need for meaningful spatial learning. It is crucial to integrate old knowledge with new knowledge in students' cognitive structures. This process requires a conducive learning environment to ensure effective knowledge transformation. *Third,* there is a need for learning that enhances the development of lifelong learner. The 21st century is characterized by a shift in the learning paradigm towards fostering lifelong learners, where students actively engage in knowledge construction and teachers act as facilitators. SBL regularly provides opportunities for both teachers and students to develop the characteristics of lifelong learners. SBL offers several advantages, such as facilitating spatial knowledge acquisition, stimulating high-level and abstract thinking skills, enabling effective teacher guidance, promoting collaborative group work, and encouraging outdoor learning activities (Handoyo & Purwanto, 2017).

A preliminary study of the SBL conducted by Manek et al. (2019) showed its positive effect on critical thinking skills. This study, conducted at the secondary school level without technology, faced difficulties during spatial orientation and analysis, hindering optimal execution. Therefore, this research complements the SBL approach by integrating it with the Spatial Mapping-QGIS approach, designated as SBL-QGIS, as part of geospatial technology. QGIS was chosen for integration with SBL because it is practical and easy to use for creating maps with complex content. Additionally, it facilitates students in building spatial knowledge and skills. As stated Pivarníková and Trojan (2023) asserted that integrating GIS tools like QGIS into geography lessons empowers students to use spatial data to understand their surroundings. They recommended ICT laboratories to motivate students, elucidate GIS theories, foster collaboration, and make learning QGIS enjoyable. Da Silva Mano and Augustijn (2023) demonstrated that students responded positively to QGIS learning experiences, significantly affecting institutional commitment to open-source software. Through the application of SBL-QGIS, it will be possible to create a learning environment that engages students in spatial phenomena, explores data and information, analyzes it spatially, develops alternative problem-solving methods, and makes spatially informed decisions. This spatial knowledge and these skills will enhance students' critical thinking abilities.

On the other hand, education in the 21st century faces multifaceted challenges, rapid and unpredictable change, and sophisticated computer-internet technology utilization (Haubrich, 2000; Lidstone & Stoltman, 2003; Pauw, 2015). Consequently, numerous authors underscored the necessity of enhancing students' critical thinking skills (Jo et al., 2010; Bednarz & Lee, 2011; Ridha et al., 2019). These skills are essential for addressing global issues across various life spheres, enabling students to identify problems, engage in reasoning to uncover issues, and propose alternative solutions (Chu et al., 2016). However, Indonesian schools currently fall short of fostering critical thinking, such as elaborating on material, contextualizing learning, and developing inference abilities (Alfajri, 2020; Permatasari, 2021).

Based on the description above, it can be stated that critical thinking is one of the 21st century skills that is important for students to master. Skills play an important role for students in dealing with the problems of their daily lives. Critical thinking skills have been proven to make a significant contribution in helping students to recognize problems factually, provide alternative solutions and act as a solution. Meanwhile, SBL using QGIS is a developed geography learning model that provides the opportunity to study phenomena spatially. However, until now the influence of SBL on students' critical thinking skills is not yet known. The findings of this research can contribute to the development of spatial-based learning with QGIS for curriculum enhancement, leading to more structured and comprehensive learning. Additionally, it can improve the quality of research in the field of spatial-based learning and its application in fostering critical thinking skills.

The purpose of this study is to know the impact of SBL-QGIS on students' critical thinking abilities. The primary research question examines the effectiveness of spatial-based learning in enhancing students' critical thinking skills. Critical thinking is assessed based on competencies such as recognizing problems, identifying, and formulating them, collecting, and organizing data, analyzing data, drawing conclusions, and reflecting on the process.

Research Question

Critical thinking is a vital skill for students, enabling them to analyze and solve complex problems. Integrating technology in education, such as Spatial-Based Learning (SBL) with QGIS, offers a unique approach to developing these skills. SBL-QGIS allows students to visualize and interpret spatial data, promoting active problem-solving, argumentation, and decision-making. This study explores how SBL-QGIS affects students' critical thinking, focusing on their abilities to formulate problems, provide arguments, draw conclusions, propose alternatives, and make decisions. The core question is: "How does Spatial-Based Learning using QGIS (SBL-QGIS) impact students' critical thinking skills in these areas?"

Hypotheses

Formulated based on a literature review, the hypotheses in this study aim to address the research question in the following manner:

The null hypothesis (H_0) posits that there is no significant difference in the critical thinking skills of students who utilize SBL-QGIS compared to those who undergo conventional learning measured by evaluating formulating problems, providing arguments, drawing conclusions, proposing alternatives, dan making decisions.

The alternative hypothesis (H_1) suggests that there exists a significant difference in the critical thinking skills of students who are exposed to SBL-QGIS compared to those who undergo conventional learning measured by evaluating formulating problems, providing arguments, drawing conclusions, proposing alternatives, and making decisions. The detailed hypotheses for each critical thinking indicator are outlined as follows:

H_1a: There is a significant difference in students' ability to formulate problems between those who use SBL-QGIS and those who undergo conventional learning.

H_1b: There is a significant difference in students' ability to provide logical and relevant arguments between those exposed to SBL-QGIS and those who undergo conventional learning.

H_1c: There is a significant difference in students' ability to draw conclusions based on data and analysis between those who use SBL-QGIS and those who undergo conventional learning.

H_1d: There is a significant difference in students' ability to propose alternative solutions between those exposed to SBL-QGIS and those who undergo conventional learning.

H_1e: There is a significant difference in students' ability to make decisions based on data analysis between those who use SBL-QGIS and those who undergo conventional learning.

Literature Review

Critical Thinking Skills

Critical thinking can be defined as an individual's capacity to perceive phenomena, situations, and ideas from a profound perspective and make decisions by evaluating the reliability of knowledge according to standards of logic and reasoning (Huckle, 2019). It involves actively and skillfully reasoning through information gathered from observations and experiences, serving as the foundation for systematic and logical decision-making processes (Changwong et al., 2018). Ennis (2011) asserts that critical thinking entails a deliberate focus on decision-making regarding beliefs or actions through reflective and rational thinking. Moreover, Lane, (2007) emphasizes that critical thinking encompasses the broader process by which an individual reflectively, argumentatively, and rationally interprets and evaluates information to formulate opinions or make judgments.

Critical thinking skills encompass a multifaceted capacity to assess and analyze information sources by integrating prior knowledge and establishing connections to derive informed conclusions (Hatcher, 2015). Broadly, critical thinking is characterized by several attributes: (1) the utilization of sound reasoning and judgment, (2) the consideration of situations from various perspectives and dimensions, (3) a willingness to embrace change and innovation, (4) engagement in unresolved or ambiguous problem-solving, (5) approaching reading materials with receptivity and impartiality, (6) employing analytical thinking methodologies, and (7) meticulous attention to details (Conklin, 2012). Consequently, indicators of proficient critical thinking include the ability to formulate problems effectively, construct cogent and logical arguments on complex issues, draw sound conclusions based on evidence, generate alternative solutions or perspectives, and facilitate decision-making processes.

In daily life, critical thinking serves as a cornerstone for decision-making, the formation of reasoned opinions, mitigation of individual biases and inclinations, and articulation of persuasive arguments in support of morally justifiable positions (Vong & Kaewurai, 2017). The cognitive dimensions of critical thinking encompass various facets, including interpretation, analysis, evaluation, drawing conclusions, providing explanations, and self-regulation. These higher-order cognitive skills provide avenues for reasoning through existing knowledge or situations, rectifying errors, and addressing limitations to attain optimal outcomes.

Critical thinking stands as a fundamental skill requiring cultivation within educational settings. It is frequently characterized as the practice of reflecting on one's own cognitive processes (Ruggiero, 2012), representing a vital component for students to enhance their cognitive abilities. Within classroom dynamics, critical thinking assumes a pivotal role. Individuals' adept in critical thinking demonstrates heightened acumen in decision-making and effectiveness in action, pose inquiries of greater complexity, and engross themselves more profoundly in the learning experience (Birgili, 2015).

In the context of education and everyday life, critical thinking is crucial for enhancing the ability to recognize and solve problems, make better decisions, and develop strong argumentation skills (Turan et al., 2019). Improving problem-solving skills helps students systematically and logically formulate and overcome challenges. Better decision-making enables students to evaluate alternatives and make more informed choices. Developing argumentation skills strengthens students' ability to construct well-founded arguments and support them with relevant evidence.

From the perspective of Bloom's taxonomy, critical thinking can be categorized into levels of understanding, application, analysis, synthesis, and evaluation (Nurmatova & Altun, 2023). Meanwhile, from the perspective of Higher Order Thinking Skills (HOTS), the emphasis is on domain of analysis, synthesis, and evaluation (Maharani et al., 2022). Problem analysis involves identifying and examining the key elements of a problem. Solution synthesis requires integrating information from various sources to design innovative solutions. Argument evaluation refers to the ability to assess the strengths and weaknesses of an argument and the proposed solution.

Based on the description above, critical thinking can be defined as the ability to reason, encompassing skills such as problem formulation, argumentation, conclusion drawing, proposing alternatives, and decision-making. Formulating a problem involves framing a question that spatially relates two or more independent variables to one dependent variable. Providing an argument requires explaining the formulated problem logically. Drawing conclusions involves inductive or deductive reasoning based on data and information from a spatial phenomenon. Proposing alternative solutions involves suggesting different ways to address spatial problems. Finally, decision-making involves selecting the most appropriate course of action from the proposed alternatives.

Spatial Learning in Geography

Geography underscores the interconnectedness of geography with human experience's spatial aspects, namely space and place, which are considered fundamental (Campbell, 2016). The core challenges in geography education revolve around specific inquiries such as "Where is it?" and "Why is it there?" These inquiries prompt individuals to contemplate context, patterns, and spatial relationships (Jo & Bednarz, 2009; Scholz et al., 2014). Understanding spatial patterns and processes is vital for comprehending human inhabitation of the Earth. Individuals adopting an approach scrutinizing spatial perspective on the Earth's surface possess spatial awareness (Heffron, 2012). Thus, the spatial dimensions of phenomena on the Earth's surface play a pivotal role in geography studies, with grasping spatial patterns and processes forming the cornerstone of geography education (Bednarz & Lee, 2011; Metoyer & Bednarz, 2017).

Spatial learning primarily involves students utilizing maps and satellite images as instructional media and learning aids (Harshman, 2015; Carrera et al., 2017). Various types of topographic and thematic maps are already integrated into geography education, including natural disaster hazard maps (Ridha et al., 2021, 2022). Additionally, diverse satellite images have been employed in geography instruction, such as images depicting areas recently affected by landslides. The utilization of such maps and satellite images facilitates the spatial depiction and assessment of area conditions, thereby enhancing learning outcomes and students' engagement in geography education (Govorov & Gienko, 2013; Metoyer, 2014).

Based on the description above, it can be stated that spatial learning is an approach that emphasizes understanding and analyzing space or place. This approach is particularly relevant in geography as it enables students to develop spatial thinking skills, which involve comprehending location, distance, direction, and the relationships between objects in space. According to the concept, there are at least five key aspects of the spatial learning: mapping, remote sensing, Geographic Information System (GIS) technology, spatial data visualization, and simulation and modeling (Handoyo & Purwanto, 2017). In more detail, spatial learning includes: (1) using maps to identify the location, patterns, and distribution of geographical phenomena. (2) creating maps to visually illustrate geographical data. (3) utilizing GIS software to collect, analyze, and visualize spatial data. (4) conducting spatial data analysis to identify trends, patterns, and relationships between various geographical phenomena. (5) using satellite imagery to study landscape changes, land use, and other natural phenomena. (6) interpreting remote sensing data to understand various natural processes and human activities. (7) creating graphs, diagrams, and other visualizations to present spatial data more clearly. (8) using three-dimensional models to visualize the topography and shape of the earth's surface. (9) Employing computer simulations to model geographical phenomena and predict future changes. (10) Developing spatial models to analyze the relationships between various geographical variables.

The foundational theories supporting spatial learning in this study draw upon Piaget's theory of cognitive development, constructivism, and Vygotsky's Zone of Proximal Development (ZPD) (Gauvain, 2008). Piaget's cognitive theory posits that the acquisition of new knowledge depends on the cognitive structures that students already possess. These structures, known as schemata, are intertwined with elements of deductive knowledge (Byrnes, 2020). As a result, students require guidance and active engagement in observing phenomena, formulating problems and hypotheses, exploring theories as foundational frameworks, collecting and analyzing data, drawing conclusions, and communicating results (Tan et al., 2005).

Constructivism posits that knowledge is constructed within students' minds based on their prior knowledge (Shumba et al., 2012; Rand, 2013). Students construct their knowledge based on their cognitive structures and are not just passive recipients of knowledge transmitted by external sources such as teachers (Larochelle et al., 1998). Learning is seen as a process of knowledge formation that requires students to make sense of new information, integrate knowledge from concrete experiences, engage in collaborative activities, and engage in interpretive reflection. Therefore, active student involvement is crucial for problem-solving, connecting new spatial information with existing knowledge to deepen understanding, directing learning toward real-world problem-solving activities, and ensuring that learning accommodates students' cultural backgrounds or daily environments.

Vygotsky's theory delineates the learning process into two stages: the collaborative stage, involving interaction with others, and the individual stage, encompassing the internalization process. During the interactional phase, both teachers and students cultivate various abilities, such as mutual respect, critical evaluation of others' assertions, negotiation, and adoption of viewpoints (Gillies, 2016; Thornberg et al., 2022). To optimize children's learning and enhance their proficiency in developing higher mental functions, attention must be directed toward the Zone of Proximal Development (ZPD), emphasizing the crucial role of guidance and effective teaching provision. Consequently, teachers play crucial roles as facilitators and mediators of student learning, implementing cooperative learning strategies to foster the development of less proficient children with the support of more skilled peers (Harland, 2003).

Spatial Based Learning-QGIS as a Learning Strategy

In geographical studies, understanding and analyzing social, economic, and environmental phenomena within a spatial and geographical framework necessitates employing a spatial approach (Fischer, 2001). This approach emphasizes observing, analyzing, and interpreting data or information concerning specific locations or places. Additionally, it proves valuable in discerning relationships between social, economic, and environmental factors and particular locations or places (Ridha & Kamil, 2021).

A spatial approach refers to a methodology or perspective focusing on the spatial dimensions and relationships within a given context (Fu, 2022). It involves analyzing and understanding how physical space, location, and arrangement affect various phenomena, including social, economic, environmental, or cultural aspects. This approach acknowledges the importance of spatial patterns, distributions, and interactions in shaping and influencing processes and outcomes. In research, a spatial approach often involves using geographic information systems (GIS), mapping techniques, and spatial analysis tools to examine and interpret data within their spatial context. This approach is particularly relevant in disciplines such as geography, urban planning, environmental science, archaeology, and sociology, where understanding spatial patterns is essential for gaining insights into complex systems and relationships.

Mapping analysis is a key component of the spatial approach technique used to identify spatial patterns of a phenomenon (Aliman et al., 2024; Ridha & Kamil, 2021). According to Wang and Chen (2013), a spatial pattern refers to the arrangement or placement of objects on the Earth's surface. Any change in the spatial pattern reflects the spatial process affected by environmental or cultural factors. The spatial pattern of a geographic object emerges from physical or social processes occurring at specific locations on the Earth's surface. These spatial patterns elucidate the distribution of geographic phenomena and facilitate their comparison with other phenomena. Various forms of data distribution in spatial patterns include random, scattered, and clustered arrangements, as illustrated in the following figures.

QGIS stands as an immensely popular open-source platform known for its user-friendly interface and licensed under the General Public License (GNU). It boasts compatibility with various platforms, including Windows, Linux, Mac, and Android versions. QGIS facilitates a broad range of spatial analyses, encompassing terrain analysis, hydrology, thematic mapping, land cover mapping, and more, utilizing both vector and raster data (Sandhya, 2020; Elakkiya & Sankarganesh, 2023). QGIS is commonly utilized for tasks related to mapping, spatial analysis, and data visualization. It stands out as a powerful and versatile GIS software, offering a wide range of tools and capabilities for working with geospatial data. This makes it invaluable for researchers, cartographers, geographers, and anyone dealing with maps and spatial information (Sparks, 2023). QGIS offers several advantages to its users. Firstly, it enables users to work with spatial data, providing a platform for handling geographic information effectively. Secondly, it offers a variety of tools and functions that allow users to view maps, edit geographic data, and perform spatial analysis tasks efficiently. Thirdly, it assists users in creating maps with multiple layers, including points, lines, polygons, as well as labels and legends, enhancing the visual representation of spatial information. Fourthly, it supports a wide range of geospatial analysis tools, empowering users to conduct operations such as buffering, spatial queries, proximity analysis, and more, facilitating in-depth spatial analysis. Finally, QGIS provides tools for visualizing data in various formats, such as thematic maps, heat maps, and other graphical representations of geographic data, aiding users in presenting their findings effectively.

According to the above description, it can be stated that SBL-QGIS is a strategy or spatial learning model that uses QGIS through steps of the spatial orientation, formulating spatial problems, collecting spatial data, organizing spatial data, analyzing spatial data, drawing conclusions, communicating findings, and reflecting of the learning process. QGIS can be used in spatial data analysis steps. After problem orientation activities, formulating problems, and collecting data, QGIS is used to digitally map the data and information obtained thematically. The thematic map will aid in spatial data analysis, making it easier to draw conclusions and identify trends.

Wider application of learning strategies and techniques can be done by: (1) engaging students in mapping activities, such as making simple maps or analyzing existing maps; (2) using thematic maps to teach concepts such as population distribution, climate, or land use. (3) direct students to conduct research projects using GIS, such as mapping specific areas and analyzing related data. (4) using GIS to study local issues, such as land use change around their school or city. (5) direct students to conduct field surveys and collect spatial data directly. (6) conducting excursions to important locations to study geographical phenomena directly.

Method

Research Design

The objective of this study was to assess the effectiveness of Spatial-Based Learning using Quantum Geographic Information System (SBL-QGIS) in enhancing students' critical thinking abilities. To achieve this objective, a quantitative research methodology was used, employing a quasi-experimental design with a pretest and post-test control group design model. Two primary variables were identified: the Spatial-Based Learning model utilizing SBL QGIS as the independent variable, and critical thinking skills as the dependent variable. The SBL QGIS framework comprises eight sequential steps: spatial orientation, formulation of spatial problems, data collection, organization of spatial data, spatial data analysis, formulation of conclusions, communication, and reflection.

Critical thinking skills comprise five key indicators: formulating problems, providing arguments, drawing conclusions, proposing alternatives, dan making decisions. The capacity to formulate problems empowers students to express their thoughts through interrogative statements probing the relationship between independent and dependent variables. Providing argumentation skills entail students providing rationales for the problems they pose. Drawing conclusions involves students employing deductive reasoning to address observed phenomena. Proposing alternative solutions requires students to propose ideas for resolving the problems they have identified.

Making decision involves students selecting the most suitable alternatives for addressing the challenges encountered. The research design employed is delineated as Table 1 follows.

Table 1

Experimental Pretest and Posttest Control Groups Design

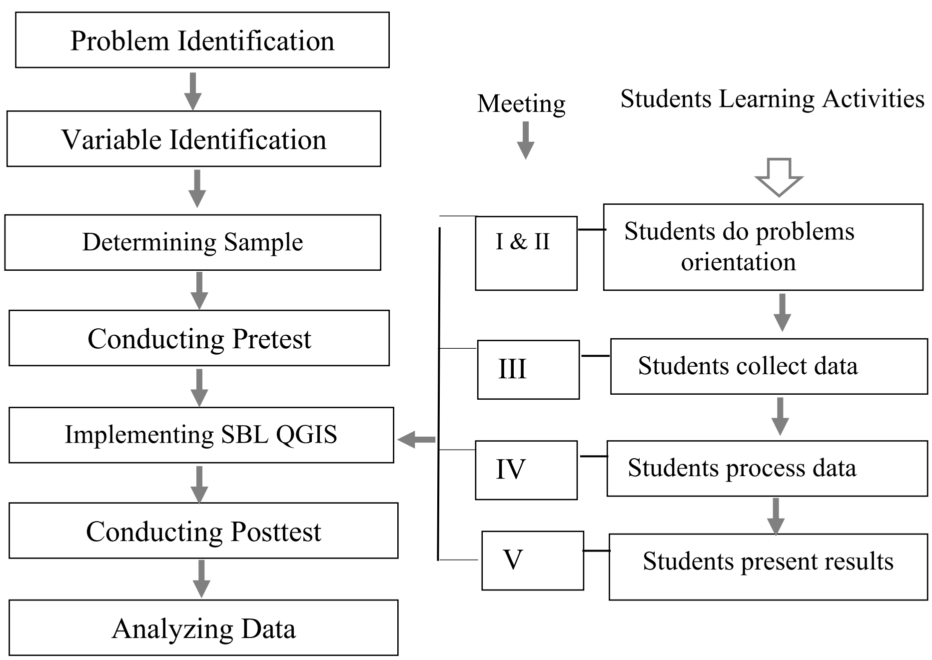
Pretest	Group	Posttest
O1	X	O2
O3	-	O4

Notes:
O1 O3 = Pretest (Critical Thinking)
O2 O4 = Posttest (Critical Thinking)

The research procedure framework delineates several stages within this study, as illustrated in the next figure 1.

Figure 1

Research Procedural Framework



The initial stage involves problem identification. The research began by acknowledging prevailing learning challenges within the field of geography. Collaborative discussions among members of the research team in 2019 identified several issues, among which the notable concern pertinent to this study was the observed deficiency in critical thinking abilities among geography students, juxtaposed with the potential of integrating spatial technology within instructional frameworks as a viable solution. However, owing to the outbreak of the COVID-19 pandemic, the initiation of the research endeavor was postponed until circumstances permitted its execution.

In the second stage, variables were delineated. Building upon the identified problems, the variables were discerned as follows: Spatial Model Learning employing QGIS constituted the independent variable, while critical thinking skills were designated as the dependent variable.

In the third stage, sample determination was undertaken. Given the resumption of normalcy in the learning environment post-COVID-19, research subjects could be identified. Accordingly, students enrolled in the Geography Education Program at FIS UM for the academic year 2023–/2024 were selected as the research subjects.

In the fourth stage, the pre-test was administered. This assessment took place prior to the implementation of SBL QGIS and was scheduled for a duration of 60 minutes. Students were seated in an orderly fashion within their respective classrooms, where they received question sheets from appointed supervisors and provided responses on distributed answer sheets.

In the fifth stage, the research commenced on October 4, 2023, and unfolded across five sessions, incorporating both indoor and outdoor activities. During the initial sessions (I and II), students engaged in spatial orientation toward disaster-related issues. Working in pairs, they delved into various natural disaster phenomena, identified spatial challenges posed by disasters, and gained insights into pertinent concepts, principles, and approaches to disaster mitigation. This process involved exploring news articles from mass media sources, analyzing images and videos, and utilizing tools such as Google Earth. Subsequently, students engaged in group discussions to investigate emerging issues stemming from natural disasters, with a particular focus on phenomena such as floods, earthquakes, and volcanic eruptions. The lecturer played a facilitative role, guiding students through their observations and facilitating group discussions. Following these discussions, students collaborated within their groups to select and formulate a singular problem based on their collective orientation findings. These formulated problem statements were then presented to other groups, with the lecturer overseeing the review of each group's proposed problem formulations.

During the third meeting, students collaborated in groups to collect data. They engaged in both direct and indirect data collection methods. Direct observations involved field visits to flood-affected areas across various districts in Malang city. Additionally, students employed indirect observation techniques utilizing social media platforms and geospatial technology. In the subsequent fourth meeting, students focused on data processing, analysis, and drawing conclusions. Each group was provided with at least one laptop equipped with the QGIS application. Working collectively, students processed raw data into tabular formats, interpreted the data within these tables, and proceeded to employ QGIS techniques to create maps. Spatial analysis was conducted utilizing integrated data within these maps. Students then correlated the results of their analyses with spatial elements to elucidate findings and draw insightful conclusions.

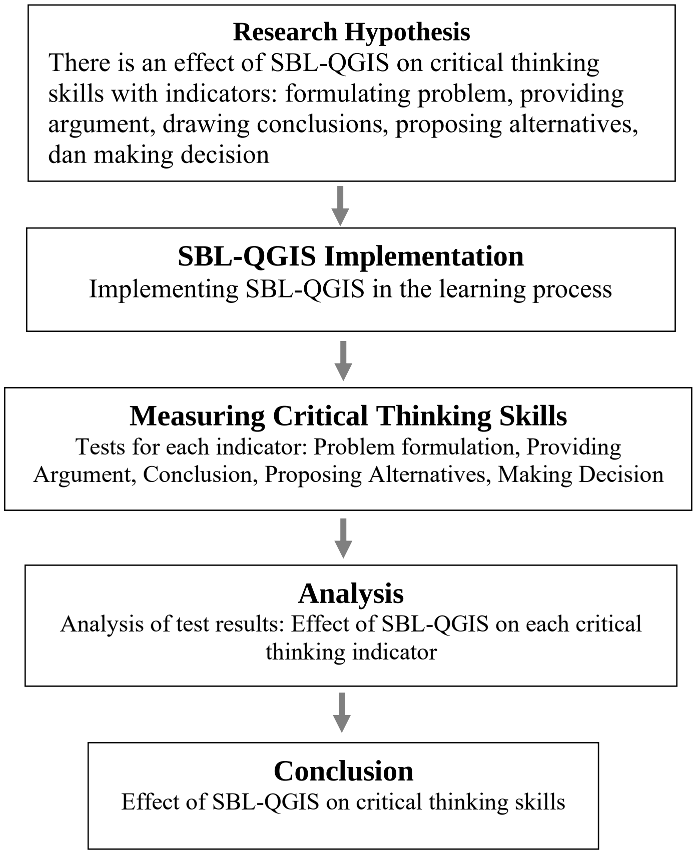
During class sessions, group work comprised two indoor sessions, each lasting 50 minutes, while the remaining activities were structured tasks conducted outside the classroom environment. In the fifth meeting, students presented their research findings and engaged in reflective exercises regarding their learning experiences. Each group was allocated five minutes for their presentation, followed by a two-minute period for questions and answers. Subsequently, following all presentations, students engaged in reflective discussions facilitated by the lecturer. These discussions encompassed inquiries into whether the learning objectives were met, students' impressions after participating in learning activities utilizing SBL QGIS, and areas identified for potential improvement in future iterations of the learning approach.

In the sixth stage, the post-test was administered after the conclusion of the SBL QGIS implementation. This assessment spanned a duration of 60 minutes. The lecturer distributed question sheets, and students provided responses on answer sheets within the allocated time frame.

In the seventh stage, data analysis was performed on the collected data utilizing SPSS for Windows. An independent sample mean difference test was employed for statistical analysis. To obtain the research findings, hypothesis testing was conducted through the process depicted in Figure 2 below.

Figure 2

Flow Chart Research Hypothesis and Testing Process



Study Sample

The subjects of this research were first-semester students from the Geography Education Program, Faculty of Social Sciences, State University of Malang, for the 2023/2024 academic year. The total number of students was 128. They were divided into two groups: the experimental group and the control group, with 60 students in each group. Sixty students were randomly selected from the entire pool to be research subjects, and then randomly assigned to one experimental class and one control class. Random selection was used to ensure that each student had an equal opportunity to be a subject in this research. The experimental group participated in learning using SBL-QGIS, while the control group followed conventional teaching methods such as speech, discussions, and assignments. The distribution of students and research subjects is presented in Table 2 below.

Table 2
Number of Research Sample

Group	Number of Students	Number of Subjects
Experiment	65	60
Control	63	60
Total	128	120

Data Collection Tools

The instrument used to collect data on critical thinking skills in this study is an essay test. The development of this instrument followed several stages: (1) Providing operational definitions for the five indicators of critical thinking: formulating problems, providing arguments, drawing conclusions, proposing alternatives, and making decisions. (2) Breaking down the five indicators into several sub-indicators and developing question items that represent these specific sub-indicators. (3) Creating an essay test format that aligns with the critical thinking sub-indicators and formulating clear and easy-to-understand prompts for each question. (4) Validating the content of the questions through expert evaluations in learning and geography, and conducting construct validity testing using the SPSS application. Revisions were made based on experts' feedback and the results of the construct validation test. (5) Testing the instrument by conducting sample trials and collecting trial data. (6) Analyzing the trial data, including validity and reliability tests, and revising or removing questions that were found to be invalid or unreliable. (7) Finalizing the instrument by refining all questions and incorporating the revised items as part of the final instrument.

To help students answer questions as intended, the instrument is accompanied by general and specific guidelines. The general guidelines provide overall instructions that students must follow when answering the questions, while the specific guidelines serve as directives for addressing each question individually. In developing a quality instrument, it is essential to conduct validity and reliability tests, as well as an anchoring process. This process aims to determine whether modifications to the instrument are necessary. The testing is based on the critical thinking instrument developed by Ennis (2011) or other appropriate critical thinking models.

This test comprises essay questions formulated by the researcher, guided by Ernis's (2011) five critical thinking indicators: problem formulation, providing argumentation, drawing conclusion, proposing alternatives, and making decision. For scoring purposes, a rubric sourced from the Center for Teaching, Learning, & Technology at Washington State University (2006) is employed. This rubric encompasses seven criteria: succinct presentation of the problem, question, or issue; consideration of context and assumptions; articulation of personal perspective, hypothesis, or stance; analysis of supporting data and evidence; incorporation of alternative viewpoints; evaluation of conclusions, implications, and ramifications; and effective communication. Following these adjustments, five essay questions were refined and utilized as measurement tools to collect the study data. The rating scale ranges from emerging to mastering, with scores ranging from 1 to 2 each. The final score is computed using the following formula:

$$Final\ score = \frac{\text{gain score}}{\text{total score}}\ x\ 100$$

Once prepared, the instrument underwent validation by Dr. Hadi Soekamto, MPd, an expert in geography learning evaluation. Expert validation was utilized for the instrument to ensure the appropriate selection of material and taxonomic level. The insights from these experts can offer valuable suggestions for improving the questions prepared by the researcher.

The instrument development process commenced in 2019 with the aim of facilitating data collection within the same year. However, due to the COVID-19 pandemic, the instrument remained unused. Subsequently, upon receiving suggestions from the validator, the research instrument underwent refinement, focusing on enhancing question content and the utilization of interrogative language. Specifically, the content was augmented to incorporate spatial data, such as detailed information on floods in specific regions and refine interrogative sentences at the analysis level.

After initial preparation, the instrument was tested for content and construct validity, as well as reliability testing. Content validity involves expert judgment to assess whether the items in an instrument cover all relevant aspects of the construct being measured, thereby ensuring comprehensive coverage. Meanwhile, construct validity refers to the extent to which an instrument accurately measures the intended theoretical construct. This is tested using statistical analysis, such as factor analysis in SPSS, to ensure that the items in the instrument are aligned with the theoretical constructs they wish to measure. The construct validity test involved 16 students as subjects.

The subjects for this instrument test comprised 35 students enrolled in the Geography Education Program who had completed the Fundamentals of Geography course. The validity test results indicated that out of the 10 essay questions examined, eight questions were deemed valid, while two questions were found to be invalid. Subsequently, five questions were selected from the eight valid questions. The five questions were: (1) Problem formulation: how is the problem formulated based on the following flood events? (2) Providing arguments: what is the argument for the problem formulation that you have prepared? (3) Making conclusions: what is your conclusion regarding the flood events that occurred in the following Indonesian capital cities? (4) Proposing alternatives: what are alternative solutions to the following flood events? (5) Making decisions: what is your decision based on the alternative solutions to the problem?

Based on the five question items, question number 3 is used as the anchor, namely the skill of making inductive conclusions from rainfall data that has occurred over 10 years. Thus, question number 3 is the same between the experimental group and the control group, while questions number 1, 2, 4, and 5 have different material, but have the same level of cognition.

The outcomes of the construct validity test are presented in Table 3.

Table 3

Results of Validity Test for Critical Thinking Skills Question Items

INDICATOR	FP	A	C	PA	MD	Total	
Formulation Problem (FP)		.006	.003	.001	.001	.000	Sig. (2 tailed)
Providing Arguments (A)	.006		.000	.000	.000	.000	
Drawing Conclusion (C)	.003	.000		.077	.000	.000	
Proposing Alternatives (PA)	.001	.000	.077		.000	.000	
Making decision (MD)	.001	.000	.000	.000		.000	
N	35	35	35	35	35	35	

Table 3 shows that the questions designed to measure the skills of formulating problems, providing arguments, drawing conclusions, proposing alternatives, and making decisions each have a significance value (Sig.) of 0.000, indicating that these questions are valid. Meanwhile, the reliability test results for the test instrument yielded a Cronbach's alpha of 0.851, indicating high internal consistency and reliability for using the test as an instrument to measure critical thinking skills.

Data Collection

Data were collected through a critical thinking ability assessment, comprising two tests: a pre-test administered prior to the introduction of SBL-QGIS learning, and a post-test administered after the implementation of this learning approach. During the test administration, the researcher received support from two test supervisors responsible for disseminating question and answer sheets and supervising the proceedings. Each test session spanned 60 minutes and commenced with a briefing on the question answering process. Upon completion of the test, officials collected the question-and-answer sheets from the participants.

The collected answer sheets were organized according to their respective offerings and subsequently evaluated by the researcher to derive scores for each question item. The assessment encompassed five questions, addressing skills in formulating problems related to flood disasters, presenting arguments supporting the formulated problems, drawing conclusions regarding the observed disasters, proposing alternative solutions to natural disaster challenges, and making decisions concerning the proposed solution alternatives alongside their justifications. Each question item carried a score range of 0–100, with equal weighting of 20%, culminating in a total weight of 100% for all questions. Criteria for evaluating the level of critical thinking proficiency were established as follows: Scores above 85 denoted Very High proficiency, scores between 71 and 85 indicated High proficiency, scores ranging from 61 to 70 signified Moderate proficiency, scores between 41 and 60 represented Low proficiency, and scores below 41 indicated Very Low proficiency. For the scoring rubric, please refer to the table 4 below.

Table 4
Scoring Rubric of the Critical Thinking

Indicators	Score				
	1	**2**	**3**	4	**5**
Problem Formulation	Did not know the problem at all	Unable to identify major problems related to natural disaster mitigation.	Identify the problem, but are less clear or not focused on the main issue.	Identify the main problem clearly, but less in-depth.	Identify key issues clearly, focused, and in-depth, and consider broader context.
Providing an Argument	Does not know arguments at all	No arguments are given or arguments are irrelevant to the topic.	Provide an argument, but the argument is not supported by sufficient data or evidence.	Provide a strong and relevant argument, supported by some data or evidence.	Provide strong, relevant, and logical arguments, supported by comprehensive and diverse data or evidence.
Conclude		The conclusion is absent or	Conclusions are drawn, but less	The conclusions are clear and largely	The conclusions are logical, relevant,

	Knowing no conclusions at all	irrelevant to the arguments or data presented.	based on data or strong arguments.	supported by the data and arguments provided.	and fully supported by the data, arguments, and analysis presented.
Filing Alternative Solutions	Does not know any problem-solving alternatives at all	Not proposing workaround alternatives or proposed alternatives are irrelevant.	Proposing one alternative solution, but less creative or less realistic.	Propose some alternative solutions that are quite creative and realistic.	Propose several solutions that are innovative, realistic, and consider various factors and perspectives.
Taking Results	Does not know decision-making at all	No decisions are taken or decisions are irrelevant.	Decide, but not consider all the available information or options.	Make good decisions, considering most of the information or options.	Make very informed decisions, consider all information and options, and demonstrate deep critical thinking.

Research Process

In the context of implementing SBL-QGIS as the intervention for the experimental group, the differences between this group and the control group are outlined as follows. For the experimental group, students are introduced to disaster mitigation issues, including the problems and impacts, from a spatial perspective. This approach uses QGIS to facilitate mapping and analyzing natural disasters. The students engage with geospatial data by processing maps, identifying disaster-prone zones, and modeling the distribution of disaster impacts. This spatial analysis is essential in understanding disaster patterns and formulating solutions based on spatial data. The learning process in the experimental group follows a structured approach through eight steps: spatial orientation, formulation of spatial problems, data collection, organization of spatial data, spatial data analysis, formulation of conclusions, communication, and reflection. This method helps students systematically approach disaster mitigation problems, fostering critical thinking at each stage of the learning process.

The treatment for this group is delivered over four weeks, with each weekly session lasting 100 minutes. In addition, QGIS-based assignments are provided, where students engage in learning scenarios and participate in group discussions designed to enhance their critical thinking skills. These discussions, guided by QGIS data and spatial scenarios, are monitored closely to ensure students use the software effectively and according to the established procedures.

In contrast, the control group receives conventional learning methods, which include lectures or text-based instruction. Students are also introduced to disaster mitigation from a spatial perspective, but this is done in a theoretical manner, without the use of QGIS for spatial analysis.

Assignments in this group consist of reading tasks, summaries, and discussions without the support of geospatial technology.

The duration and structure of the learning process in the control group mirror that of the experimental group, with four weeks of sessions and 100 minutes per session. To maintain consistency, learning activities in the control group are similarly monitored, ensuring students follow the traditional methods of learning the material. Despite the differences in instructional methods, there are some similarities between the two groups. Both the experimental and control groups take the same pretest and posttest to evaluate their critical thinking skills, focusing on aspects such as problem formulation, argumentation, inference, alternative solutions, and decision-making. Additionally, both groups are closely monitored to ensure that no other variables interfere with the study outcomes, apart from the differences in the learning methods used.

Once the treatment is completed, the pretest and posttest results are analyzed by comparing the gain scores between the experimental and control groups. This analysis is designed to measure the effectiveness of SBL-QGIS in improving critical thinking skills compared to the conventional learning approach. The differences in critical thinking gains provide insights into whether the SBL-QGIS approach significantly enhances students' abilities in problem-solving and decision-making. To control other variables in the study, it is ensured that the teachers for both groups share similar educational backgrounds and use comparable pedagogical approaches in their communication style, with the only difference being the instructional method (SBL-QGIS vs. conventional). Furthermore, the learning environment, duration of study, and the learning materials (except for the use of technology and learning scenarios) are kept consistent between the two groups, ensuring that the observed differences in outcomes are attributable to the instructional methods rather than external factors.

Data Analysis

The critical thinking skills data collected was analyzed using the following framework. First, data is collected using instruments that have been tested for validity and reliability, ensuring that the data obtained is valid and reliable. Second, the collected data was tested for homogeneity and normality. If the significance value (sig) is greater than 0.05 then the data is considered normal and homogeneous. The homogeneity test results for critical thinking skills data show a significance value of 0.781, which is greater than 0.05. Therefore, it can be stated that the critical thinking skills data between the experimental and control classes are homogeneous. For the normality test, a significance value of 0.133, which is greater than 0.05, was obtained. This indicates that the critical thinking skills data from the test results can be considered normal. The results of calculating the levels of homogeneity and normality can be seen in the following Table 5.

Table 5

Test of Homogeneity of Variances

Critical Thinking Skills			
Leven Statistic	Df1	Df2	Sig
.78	1	118	.781

Table 6

Tests of Normality

Group	Shapiro-Wilk		
	Statistic	Df	Sig.
Pre-Test Experiment Group	.969	60	.133
Pre-Test Control Group	.971	60	.161

Third, the Independent Sample t-test was carried out using SPSS for Windows 22 at a significance level of 5%.

The independent sample t-test decision making process is as follows:

If the significance value (2-tailed) > 0.05 then H0 is accepted and H1 is rejected.

If the significance value (2-tailed) < 0.05 then H0 is rejected and H1 is accepted.

To ensure there is a relationship between the SBL-QGIS variable and the critical thinking variable, which includes indicators such as formulating problems, providing arguments, drawing conclusions, proposing alternatives, dan making decisions, and to prevent misinterpretation, a linearity test was conducted, with the following results.

Table 7

Linear test results of the Critical Thinking Indicators

Indicators	Control Group Sig	Experiment Group Sig
Critical Thinking	0.063	0.490
Problem Formulation	0.090	0.205
Providing Argumentation	0.072	0.198
Drawing Conclusion	0.062	0.424
Proposing Alternatives	0.054	0.725
Making Decision	0.089	0.632

The results of the deviation from linearity test in Table 7 showing a linear correlation between the SBL-QGIS variable and critical thinking in both the experimental and control groups. This means that an increase in the score as an impact of implementing the learning strategy will be followed by an increase in the critical thinking score.

Findings

Students' Critical Thinking

Fostering critical thinking skills among students is a fundamental objective in education, necessitating proficiency in their development. Table 8 presents the percentage scores garnered by both experimental and control groups across pre-test and post-test assessments.

Table 8
Pre-Test Score of Critical Thinking Skills

Score		Experiment group		Control group	
		F	%	F	%
> 85	Very high	-	-	-	-
71- 85	High	10	16.66	10	16.66
61-70	Medium	16	26.68	16	26.68
41-60	Low	23	38.33	24	40.00
< 41	Very low	11	18.33	10	16.66
Total		60	100	60	100

Table 8 highlights a predominant trend wherein most students, across both experimental and control groups, exhibited low-level critical thinking skills, with a few demonstrating high-level capabilities. This prevalence of low critical thinking skills shows shortcomings in their aptitude to formulating problem (FP), providing arguments (A), drawing conclusions (C), proposing alternatives (PA), dan making decisions (MD). For a comprehensive breakdown of scores corresponding to each critical thinking indicator, please refer to Table 9.

Table 9

Pre-Test Scores of Critical Thinking Skills Indicators for the Experimental Group

Score	Experiment group									
	FP		A		C		PA		MD	
	F	%	F	%	F	%	F	%	F	%
> 85 Very high	-	-	-	-	-	-	-	-	-	-
71 - 85 High	6	10.00	12	20.00	7	11.88	5	8.00	7	11.88
61 - 70 Medium	19	31.66	15	25.00	19	31.46	21	35.00	11	18.33
41 - 60 Low	22	36.66	18	30.00	23	38.33	20	34.00	31	51.56
< 41 Very low	13	21.68	15	25.00	11	18.33	14	23.00	11	18.33
Total	60	100	60	100	60	100	60	100	60	100

Table 9 presents the pre-test scores for each critical thinking indicator within the experimental group. The data indicate that a significant portion of students exhibited critical thinking skills at a low level across various dimensions, including formulating problems (FP), providing arguments (A), drawing conclusions (C), proposing alternatives (PA), dan making decisions (MD), with only a minor fraction demonstrating proficiency in these domains. A comparable distribution of scores is observed in the control group, as illustrated in the subsequent Table 10.

Table 10

Pre-Test Scores of Critical Thinking Skills Indicators for the Control Group

Score	Control group									
	FP		A		C		PA		MD	
	F	%	F	%	F	%	F	%	F	%
> 85 Very high	-	-	-	-	-	-	-	-	-	-
71 - 85 High	9	15.00	8	13.33	10	16.66	8	3.33	10	16.66
61-70 Medium	16	26.66	17	28.33	21	35.00	20	33.34	19	31.66
41-60 Low	22	36.68	19	31.68	19	31.68	18	30.00	18	30,00
< 41 Very low	13	21.66	16	26.66	10	16.66	14	23.33	13	21.68
Total	60	100	60	100	60	100	60	100	60	100

Table 10 presents the pre-test scores for each critical thinking indicator within the control group. The data show that a significant majority of students exhibited a low level of critical thinking proficiency across dimensions such as formulating problems (FP), providing arguments (A), drawing conclusions (C), proposing alternatives (PA), dan making decisions (MD), with only a minority demonstrating competence in these areas. The subsequent table, Table 11, presents the post-test results for critical thinking skills among students in both the experimental and control groups.

Table 11

Post-Test Scores of Critical Thinking Skills for Experimental and Control Groups

Scores	Experiment group		Control Group	
	F	%	F	%
> 85 Very high	21	35.00	7	11.65
71 - 85 High	25	41.66	20	33.32
61-70 Medium	14	23.34	21	35.00
41-60 Low	-	-	12	20.33
< 41 Very low	-	-	-	-
Total	60	100	60	100

Table 11 presents that a significant majority of students in the experimental group demonstrated critical thinking skills categorized at the high level, while only a minor proportion exhibited skills at the low level. In contrast, within the control group, although some students showcased high-level critical thinking skills, a substantial portion displayed skills at a low to medium level. Figure 3 below illustrates the percentage of critical thinking skills scores derived from the pretest and posttest results of both the control and experimental groups.

Figure: 3

Percentage Score Pretest and Posttest of Critical Thinking Skills

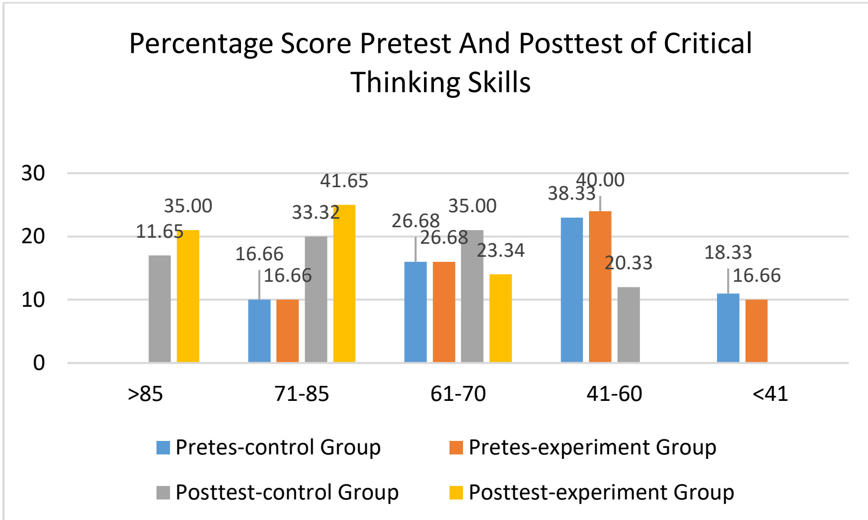


Figure 3 illustrates the pre-test scores of students in both the control and experimental groups, revealing that their critical thinking skills were similarly low, with no statistically significant differences between the groups. In contrast, the post-test scores demonstrated a marked improvement in both groups, particularly in the experimental group, where no students exhibited very low critical thinking skills. This suggests that the implementation of SBL-QGIS had a measurable and positive effect on enhancing students' critical thinking abilities. For a detailed breakdown of scores for each indicator, refer to Table 12 below.

Table 12

Post-Test Scores of Critical Thinking Skills Indicators for the Experimental Group

Score	Experiment group									
	FP		A		C		PA		MD	
	F	%	F	%	F	%	F	%	F	%
> 85 Very high	17	28.34	18	30.00	25	41.66	21	35.00	22	36.66
71 - 85 High	27	45.00	27	45.00	23	38.34	20	33.34	21	35.00
61-70 Medium	16	26.66	15	25.00	12	20.00	19	31.66	17	28.34
41-60 Low	-	-	-	-	-	-	-	-	-	-
< 41 Very low	-	-	-	-	-	-	-	-	-	-
Total	60	100	60	100	60	100	60	100	60	100

Table 12 presents that a significant majority of students in the experimental group demonstrated high-level critical thinking skills across various dimensions, including formulating problem (FP), providing argument (A), drawing conclusion (C), proposing alternatives (PA), dan making decision (MD). Conversely, a smaller proportion of students demonstrated critical thinking skills categorized in the low level. A comparable distribution of scores is observed in the control group, as depicted in the subsequent Table 13.

Table 13

Post-Test Scores of Critical Thinking Skills Indicators for the Control Group

Score	Control Group									
	FP		A		C		PA		MD	
	F	%	F	%	F	%	F	%	F	%
> 85 Very high	8	13.34	6	10.00	11	18.33	8	13..33	8	13..33
71- 85 High	21	35.00	22	36.67	16	26.67	16	26.66	19	31.67
61-70 Medium	21	35.00	21	35.00	22	36.67	25	41.66	21	35.00
41-60 Low	10	17.66	11	18.43	11	18.33	11	18.33	12	20.00
< 41 Very low	-	-	-		-		-		-	
Total	60	100	60	100	60	100	60	100	60	100

Table 13 presents the post-test scores for each critical thinking indicator among the control group. Most students demonstrated high-level critical thinking proficiency in formulating problem, providing argument, drawing conclusion, proposing alternatives, dan making decision. However, there was a minority of students with critical thinking skills at the low level.

Figure 4 below presents an illustration of the average critical thinking scores for both the control and experimental groups.

Figure 4

Graph of the Critical Thinking Scores Average of the Control and Experiment Group

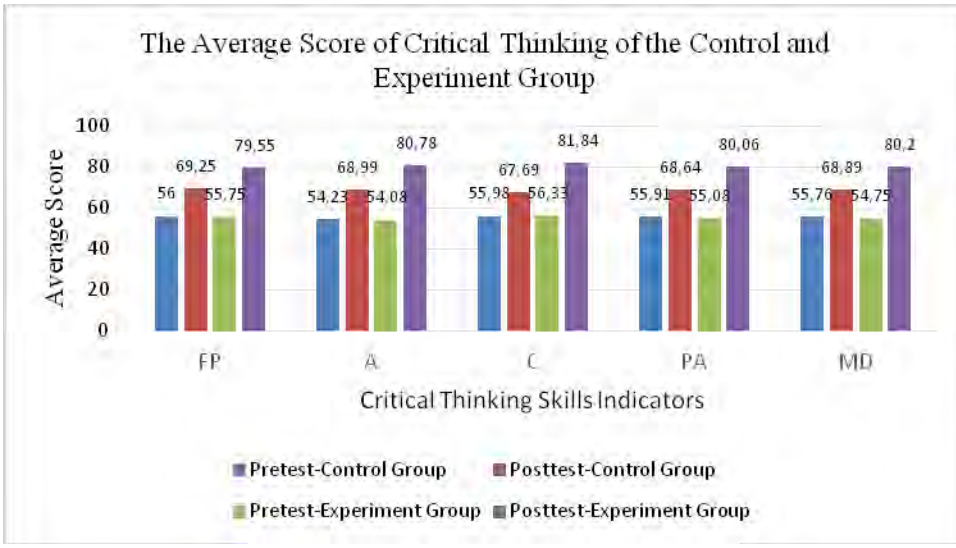


Figure 4 presents the average pre-test scores of the control and experimental groups, showing minimal differences across all critical thinking indicators: problem formulation, argumentation, conclusion drawing, proposing alternatives, and decision making. However, in contrast, the post-test scores reveal notable differences between the control and experimental groups for all critical thinking indicators. The comparison between the pre-test and post-test results highlights the impact of implementing SBL-QGIS on critical thinking skills.

Effect Spatial Based Learning QGIS on Students' Critical Thinking

The influence of SBL-QGIS on critical thinking skills will be visible when compared with conventional learning. The following is a hypothesis regarding the impact of SBL-QGIS on critical thinking skills. The following hypothesis relates to the influence of SBL-QGIS on analytical skills.

H_0 = there is no significant difference in the critical thinking skills of students who utilize SBL-QGIS compared to those who learn conventional learning.

H_1 = there is a significant difference in the critical thinking skills of students who are exposed to SBL-QGIS compared to those who undergo conventional learning.

The average test results with SPSS are shown in Table 14 below.

Table 14

Average Gain Score of Critical Thinking

Group	Number subject and average score of critical thinking					
	N	Pre-test	Post test	Gain score	Increasing (%)	Sig
Experiment	60	55.36	80.33	24.96	45,08	0.000
Control	60	55.70	68.46	12.76	22,90	

The average pre-test scores for critical thinking skills in the experimental and control groups were very similar. However, after using SBL-GIS in the experimental group, there was a significant increase in the average score compared to the control group, which employed methods such as speech, discussions, question-and-answer sessions, and assignments. The experimental group achieved an average gain score of 45.08%, exceeding the control group's score of 22.90%. The test results for the average gain scores between the two groups showed a significance level of 0.000 ($p < 0.05$), indicating a substantial difference between the average gain scores of the experimental and control groups. This highlights the impact of SBL-QGIS in enhancing students' critical thinking skills. Additional insight into the variance of mean scores for each critical thinking indicator is presented in Table 15.

Table 15

Average Gain Score of Critical Thinking Skills Indicator of the Control and Experimental Group

Indicators	Average gain score control group	Average gain score experiment group	Sig
Formulating problem	13.35	23.80	0.000
Providing arguments	14.76	26.70	0.000
Making conclusion	11.71	25.51	0.000
Proposing alternatives	12.73	24.98	0.000
Making decision	13.13	25.45	0.000

There is a significant difference in average gain scores between the control and experimental groups across various indicators, including problem formulation, providing argumentation, making conclusions, proposing alternatives, and making decisions. This underscores the substantial impact of SBL-QGIS in enhancing each facet of critical thinking skills. The following section presents an in-depth analysis of the research findings, with a focus on the five indicators of critical thinking as follows.

The Effect of SBL-QGIS on Problem Formulation

Problem formulation is a statement describing a gap between expectations and reality. Problem formulation skills have an important role in strengthening critical thinking. The influence of SBL-QGIS learning on the skills to formulate problems becomes real when compared with conventional learning. The following hypothesis answers the influence of SBL-QGIS on problem formulation skills.

H_0= There is no significant difference between the SBL-QGIS on students' critical thinking skills based on the problem-formulating skill indicators.

H_1 = There is a significant difference between the SBL-QGIS and students' critical thinking skills based on the indicator of problem formulation skills.

The average test results are seen in the following Table 16.

Table 16

Difference in Average Gain Score Control Group and Experiment Group

Indicator	Gain Score		Sig
	Control Group	Experiment Group	
Problem Formulation	13.35	23.80	0.000

Table 15 and 16 shows a significance value of 0.00, which is lower than 0.05, indicating a significant difference in the problem formulation indicators between the experimental and control groups. This difference was increasingly evident in the post-test results, where the experimental group outperformed the control group. The average score of the experimental group, which applied SBL-QGIS learning, reached 23.80, compared to the control group’s average score of 13.35 using conventional learning. The results of the average test confirm that the H1 hypothesis is accepted and the H0 hypothesis is rejected, suggesting that the SBL-QGIS model positively affects problem formulation as an indicator of the critical thinking skills.

The Effect of SBL-QGIS on Providing Argumentation

The skill of giving arguments is an important component of critical thinking. Providing an argument involves constructing, presenting, and maintaining a coherent train of thought to support a particular conclusion or point of view. These skills are crucial for evaluating evidence, making decisions, and engaging in effective problem-solving. Providing arguments plays a significant role in strengthening critical thinking. The impact of SBL-GIS learning on the ability to give arguments becomes evident when compared with conventional learning. The following hypothesis addresses the influence of SBL-QGIS on argumentation skills.

H_O = There is no significant difference between the SBL-QGIS on students' critical thinking skills based on the indicators of providing argumentations.

H_1 = There is a significant difference between the SBL-QGIS on students' critical thinking skills based on the indicator of providing argumentations.

The average test results are seen in the following Table 17.

Table 17

Difference in Average Gain Score Control Group and Experiment Group

Indicator	Gain Score		Sig
	Control Group	Experiment Group	
Providing Arguments	14.76	26.70	0.000

The average test results in Table 15 and 17 show a significance value of 0.00, which is lower than 0.05, indicating a significant difference in the providing arguments indicators between the experimental and control groups. This difference is increasingly evident in the posttest results, where the experimental group outperforms the control group. The average score of the experimental group, which applied SBL-QGIS learning, reached 26.50, compared to the average score of the control group that used conventional learning, which was 14.76. The results of the average test confirm that hypothesis H1 is accepted and hypothesis H0 is rejected, suggesting that the SBL-QGIS model positively affects providing arguments as an indicator of critical thinking skills.

The Effect of SBL-QGIS on Making Conclusion

Conclusion-making skill is an important component of critical thinking. The ability to making conclusion is crucial for comparing SBL-QGIS learning with conventional teaching methods to evaluate their impact on students' making conclusion skills. The following hypothesis relates to the influence of SBL-QGIS on making conclusion skills.

H_O = There is no significant difference between the SBL-QGIS and students' critical thinking skills based on the indicator of making conclusion skills.

H_1 = There is a significant difference between the SBL-QGIS on students' critical thinking skills based on the indicator of making conclusion skills.

The average test results are seen in the following Table 18.

Table 18

Difference in Average Gain Score Control Group and Experiment Group

Indicator	Gain Score		Sig
	Control Group	Experiment Group	
Making Conclusion	11.71	25.51	0.000

Table 15 and 18 shows a significance value of 0.00, which is lower than 0.05, indicating a significant difference in the indicators for drawing conclusions between the experimental and control groups. This difference is increasingly evident in the posttest results, where the experimental group outperforms the control group. The average score of the experimental group, which applied SBL-QGIS learning, reached 25.51, compared to the control group's average score of 11.71 using conventional learning. These results confirm that hypothesis H1 is accepted and hypothesis H0 is rejected, suggesting that the SBL-QGIS model positively affects making conclusion as an indicator of critical thinking.

The Effect of SBL MGIS on Proposing Alternatives

The skill of suggesting alternatives is an important component of critical thinking skills. This skill is crucial for comparing SBL-QGIS learning with conventional teaching methods to evaluate their impact on students' ability to suggest alternatives. The following hypothesis relates to the effect of SBL-QGIS on the skills of suggesting alternatives.

H_0 = There is no significant difference between the SBL-QGIS on students' critical thinking skills based on the indicators of suggesting alternatives skills.

H_1 = There is a significant difference between the SBL-QGIS and students' critical thinking skills based on the suggesting alternatives skill indicator.

The average test results can be seen in the following Table 19.

Table 19

Difference in Average Gain Score Control Group and Experiment Group

Indicator	Gain Score		Sig
	Control Group	Experiment Group	
Proposing Alternatives	12.73	24.98	0.000

Based on the average test results shown in Table 15 and 19, a significance value of 0.00 was obtained, which is lower than 0.05. The test results show significant differences in the indicators for proposing alternatives between the experimental and control groups. This difference was increasingly evident in the posttest results, where the experimental group outperformed the control group. The average score of the experimental group, which applied SBL-QGIS learning, reached 24.98, compared to the control group's average score of 12.73 using conventional learning. The average test results confirm that hypothesis H1 is accepted and hypothesis H0 is rejected. This indicates that the SBL-QGIS learning model positively affects to the proposing alternatives as an indicator of critical thinking skills.

The Effect of SBL MGIS on Making Decision

The skills of decision-making are a crucial component of critical thinking skills. The process of making decisions is essential for comparing SBL-QGIS learning with conventional teaching methods to evaluate their impact on students' decision-making abilities. This leads to the following hypothesis: SBL-QGIS significantly influences students' decision-making skills compared to conventional teaching methods.

H_0 = There is no significant difference between the SBL QGIS on students' critical thinking skills based on decision making skill indicators.

H_1 = There is a significant difference between the SBL-QGIS on students' critical thinking skills based on the indicator of decision skills.

The average test results can be seen in the following Table 20.

Table 20

Difference in Average Gain Score Control Group and Experiment Group

Indicator	Gain Score		Sig
	Control Group	Experiment Group	
Making Decision	13.13	25.45	0.000

Based on the average test results shown in Table 15 and 20, the significance value obtained is 0.00, which is lower than 0.05. These findings indicate significant differences in decision-making indicators between the experimental and control groups. This difference was clearly visible in the posttest results, where the experimental group outperformed the control group. The average score of the experimental group, which applied SBL-QGIS, reached 25.45, compared to the control group's average score of 13.13 using conventional learning. The average test results confirm that hypothesis H1 is accepted and hypothesis H0 is rejected, indicating that the SBL-QGIS learning model positively affects decision-making skills as an indicator of critical thinking. A summary of hypothesis testing can be seen in Table 21 below.

Table 21

Summary of hypothesis testing

Hypothesis	Average Gain Score		P-value	Significance Level (α)	Decision
	Experiment Group	Control Group			
H_0: No significant difference of Critical thinking skills H_1: Significant difference exists of Critical thinking skills	24.96	12.76	0.000	0.05	Accept H_1 Reject H_o
H_0: No significant difference of formulating problem skills H_1: Significant difference exists of formulating problem skills	13,35	23.80	0.000	0.05	Accept H_1 Reject H_o
H_0: No significant difference of provide argumentation H_1: Significant difference exists of provide argumentation	14.76	26.70	0.000	0.05	Accept H_1 Reject H_o
H_0: No significant difference of drawing conclusion H_1: Significant difference exists of drawing conclusion	11.71	25.51	0.000	0.05	Accept H_1 Reject H_o
H_0: No significant difference of propose alternative H_1: Significant difference exists of propose alternative	12.73	24.98	0.000	0.05	Accept H_1 Reject H_o

H_0: No significant difference of making decision H_1: Significant difference exists of making decision	13.13	25.45	0.000	0.05	Accept H_1 Reject H_o

Discussion

This research aims to explore the impact of Scenario-Based Learning using Quantum Geographic Information System (SBL-QGIS) on critical thinking skills, including the problem formulation, providing argumentation, making conclusion, proposing alternatives, and making decision. Each of these indicators will be examined in the following sections, followed by a comprehensive discussion of the overall influence of SBL-QGIS on critical thinking.

Student Problem Formulation Ability in SBL QGIS

Research findings indicate that the application of SBL-QGIS significantly enhances students' problem-formulation skills (Table 16). Problem formulation is the development of arguments or scientific reasons to identify the problem statement. The problem statement consists of research questions derived from the research problem (Farrugia et al., 2010). Problem formulation requires theoretical ability as well as knowledge about understanding the context of the problem (Farrugia et al., 2010). Therefore, in problem formulation, it is necessary to study theory, discuss with parties considered to have a mastery of the problem's context, analyze secondary data, and conduct preliminary research or a combination of these.

Students engaged in SBL-QGIS can articulate geographic phenomena with greater precision and consistency compared to those relying on conventional methods. QGIS has proven to be a powerful tool, enabling students to access spatial data that supports more comprehensive and in-depth analyses. The accessibility of this spatial data allows students to identify and formulate problems with greater accuracy. Moreover, it enhances their ability to analyze broader issues, which involve complex cognitive processes such as problem identification, analysis, evaluation, and reflection, thereby strengthening their critical thinking abilities.

In this context, students use QGIS to analyze the impact of flood disasters on the Brantas River flow patterns in Batu City, identifying problems such as deforestation, land use changes, and soil erosion. In SBL QGIS, students are involved in collecting data about the flooding, as well as mastering the ideal aspects of spatial management, including the proper use of land. They formulate problems based on the empirical evidence, demonstrating a significant improvement in their critical thinking skills.

SBL QGIS on Providing Argumentation

Data analysis results indicate that SBL-QGIS significantly enhances students' argumentation skills (Table 17). Students engaged in SBL-QGIS can formulate stronger arguments based on spatial data. Argumentation skills are closely related to the formulation of the problem at hand. Therefore, effective argumentation involves providing logical reasons based on the relationship between data, concepts, and theories relevant to the problem being addressed (Fatmawati et al., 2018).

The use of QGIS in learning provides spatial data and information, enabling students to view and analyze problems comprehensively (Andayani et al., 2022). Access to this data helps students develop robust arguments supported by evidence, thereby improving their ability to evaluate broader problems and connect various concepts (Andayani et al., 2022). According to Nursisto (1999) data and evidence are crucial for constructing valid arguments. For instance, students use QGIS to analyze land use changes in Batu City, identify factors affecting these changes, and formulate arguments based on the evidence. Data on land use, the size of areas used, plant types, and management systems serve as the basis for their arguments. They present their arguments through presentations or written reports, demonstrating notable improvements in their critical thinking skills.

SBL-QGIS on Making Conclusions

Table 18 shows a significant difference in the average scores of students' making conclusion skills. Students engaged in SBL-QGIS scored higher in making conclusions than those in traditional learning. In general, a conclusion is a brief statement derived from an analysis, discussion of a narrative, or the outcome of a conversation (Zamani & Ebadi, 2016). A good conclusion is not based on assumptions but on data. SBL-QGIS enables students to draw better conclusions based on field data, such as flood disaster data in Batu City. Data on flooding over the past 10 years is collected, including its intensity and distribution, and students practice drawing conclusions from data trends and distribution. QGIS was able to helps provide comprehensive spatial data, allowing students to evaluate information thoroughly and draw evidence-based conclusions (Andayani et al., 2022).

Improving making conclusion skills also enhances students' ability to analyze other information around them. This process involves higher-level thinking aspects, strengthening their critical thinking skills. For example, students using QGIS to analyze flood disasters in Malang City's local ecosystem evaluated various factors and drew conclusions based on the evidence.

SBL-QGIS on Proposing Alternatives

Research findings show that using QGIS in Scenario-Based Learning (SBL) significantly enhances students' skills in proposing alternative solutions to problems (Table 19). Alternative problem solving involves generating several formulations that can serve as potential solutions to the issues encountered (Sulasmono, 2012). This skill is crucial for students, as effectively solving problems provides them with experience and enables them to apply their knowledge and skills to real-life situations (Purnamasari & Setiawan, 2019; Suryani et al., 2020).

Data collection is a critical stage in problem solving. Spatial learning with QGIS enables students to identify and propose various alternative solutions to geographic problems (Andayani et al., 2022). QGIS offers extensive spatial data for analysis, helping students develop diverse, effective, and innovative solutions. As students' ability to propose alternatives improves, their capacity to evaluate each alternative, consider its consequences, and select the best solution also increases. This process involves critical and reflective reasoning, thereby strengthening their overall critical thinking skills. For example, students analyzing land use changes in Batu City using QGIS identified several sustainable management alternatives. They evaluated each alternative with spatial data, made informed decisions, and demonstrated significant improvement in their critical thinking skills.

SBL-QGIS on Making Decisions

The result of the study shows that using QGIS in Scenario-Based Learning (SBL) significantly improves students' decision-making skills (Table 20). Decision-making involves selecting alternative actions to achieve specific goals or targets. Key elements in decision-making include defining goals, identifying decision alternatives, evaluating unknown factors, and determining the means and tools for disseminating results. One crucial factor influencing decision-making is the availability of accurate data (Amalia & Firmadhani, 2023). Students who engage in spatial technology learning can make better decisions based on spatial data related to geographic problems. QGIS offers precise and relevant spatial data, facilitating comprehensive analysis of various aspects of a problem (Sutton et al., 2023). For instance, in this study, students used QGIS to analyze the impacts of climate change on land use patterns and evaluate different policy alternatives to mitigate these impacts. They made disaster mitigation decisions based on flood data from the city of Batu. Such decision-making experiences can enhance critical thinking skills.

Student Critical Thinking Skills on Spatial Based Learning QGIS

The results of this experimental research demonstrate a significant increase in students' critical thinking abilities following the implementation of SBL-QGIS (see Table 14). The experimental group using SBL-QGIS showed a greater improvement in critical thinking scores compared to the control group, which followed conventional learning methods. These findings are supported by evidence that SBL-QGIS significantly influences the five indicators of critical thinking: formulating problem, providing argumentation, drawing conclusion, proposing alternatives, and making decision (See Table 15).

Critical thinking plays a crucial role in helping students address complex problems in their daily lives. When students possess strong critical thinking skills, they are better equipped to solve both academic and real-world issues. Consequently, developing learning methods that enhance student engagement using technology is an important solution. The integration of QGIS into SBL has enriched the learning process, particularly by involving students in formulating problem, providing arguments, drawing conclusion, proposing alternatives, and making decision. This study has shown that QGIS significantly aids students in mapping flood-prone areas in Batu.

These findings are in line with constructivist and cognitive theories. Constructivist theory posits that students learn most effectively when they are actively engaged in the learning process (Shumba et al., 2012; Rand, 2013). SBL-QGIS enables students to build their own knowledge through the exploration and analysis of spatial data, aligning with constructivist principles that emphasize active learning and independent discovery. From a cognitive perspective, the analysis of complex spatial data enhances higher-order thinking skills (Gauvain, 2008). Through QGIS, students are presented with challenging tasks that require the application, analysis, and evaluation of information—core components of critical thinking.

These findings highlight the importance of integrating SBL-QGIS into geography curriculum. A curriculum designed with GIS technology can foster critical thinking skills essential for addressing complex environmental challenges in Indonesia. However, this study is limited by its sample size and duration. Future research should aim to expand the sample size and extend the study duration to provide more comprehensive insights.

This finding was also in line with, and support, previous research conducted by Manek et al. (2019), which also highlighted the positive impact of SBL on critical thinking skills. Although both studies show similar supportive results, the previous research was conducted at a certain secondary school level and did not utilize spatial technology. In contrast, this research was conducted with higher education students and used QGIS, making the results more convincing. University students generally have broader spatial knowledge than middle school students. This means that the implementation of SBL-QGIS has shown a significant impact on the critical thinking skills of both high school students and university students where this study took place which also highlighted the positive impact of SBL on critical thinking skills. However, notable distinctions exist between the two studies. While the previous study concentrated on specific high school students and did not utilize spatial technology, our research targeted students in higher education and employed QGIS. This disparity in educational levels and the utilization of technology serves as differentiating factors between the two studies.

The findings of this research resonate with the perspective put forth by Butterworth and Thwaites (2013), who argue that observation, analysis, inference, communication, and problem-solving constitute foundational practices in nurturing critical thinking skills. For instance, observation fosters the capacity to identify novel problems and aids in understanding potential challenges, even enabling individuals to anticipate future obstacles. Engaging in analytical tasks encourages students to locate and collect facts, data, or information relevant to important issues. This process involves acquiring unbiased information, posing pertinent questions to ensure data accuracy, and objectively assessing the findings. Furthermore, transforming data into graphical representations or tables and interpreting them enhances analytical thinking skills, which are central to fostering critical thinking abilities.

The study findings are also supported by existing studies in the field of education, particularly those investigating the utilization of geospatial technology. Mahapoonyanont (2010) concluded that a relationship exists between learning and teaching methodologies, learner factors, individual factors, and considerations pertaining to critical thinking skills. Similarly, Slameto, (2017) demonstrated that the cultivation of critical thinking habits is affected by the learning environment, which facilitates exposure to new situations, mastery of previous course material, and motivation for student engagement. Andrews (2015) and Hasnunidah et al., (2020) emphasized that prioritizing argumentation serves as an effective strategy for nurturing students' critical thinking in higher education settings. Additionally, Turan et al. (2019) highlighted that the incorporation of diverse decision-making techniques positively contributes to enhancing the quality of individuals' critical thinking capabilities.

Furthermore, the adoption of SBL-QGIS can enhance students' proficiency in problem identification and analysis. This spatial approach coupled with technology provides spatially distributed data essential for student analysis. For instance, in a study utilizing spatial technology, students were presented with population data spatially distributed across the city of Malang. Subsequently, they engaged in spatial data analysis to discern underlying patterns and trends. Studies by Kim and Bednarz (2013) and Kim (2019) indicate a positive correlation between GIS learning and critical spatial thinking. According to Yap et al. (2008), GIS and Satellite Remote Sensing serve as highly effective tools across various subjects in the NSS curriculum, particularly Geography and Liberal Studies. Additionally, studies by Bearman et al. (2016) suggest that learning with GIS encompasses a broad spectrum, extending beyond the technical aspects of software utilization to encompass the entire process of identifying spatial problems and making decisions, thereby empowering graduates to strengthen critical spatial thinking skills in higher education settings. Birgili (2015) highlighted the role of problem-based learning environments in cultivating critical thinking within classroom settings. Students who actively engage in critical thinking are inclined to pose more challenging questions and participate more dynamically in the learning process. This assertion is further corroborated by Changwong et al., (2018), who underscored that individuals adept at employing critical thinking skills frequently raise more probing questions and demonstrate heightened involvement in learning activities. Additionally, Ruggiero (2012) asserted that critical thinkers meticulously evaluate their initial impressions, differentiate between different options, and ground their conclusions with evidence rather than relying solely on personal emotions.

Moreover, critical thinkers demonstrate sensitivity to their own limitations and biases. They regularly reassess the logic of their thinking and the viability of their solutions, identifying imperfections, complexities, and anticipating potential objections. This ongoing process enables them to continuously refine their ideas (Dwyer, 2023). Ennis (2011) further elaborated on the attributes of critical thinkers, emphasizing their capacity to make judgments, clarify and enhance their perspectives, seek validation for correct viewpoints, and engage in imaginative thinking by integrating reasoned viewpoints with empathy toward others. Additionally, critical thinkers possess the capability to focus on questions supported by arguments derived from credible sources. The perspective presented aligns with cognitive development theory, which asserts that adolescents aged fifteen and older reach the formal operational stage. In this stage, individuals transcend concrete experiences and engage in abstract thinking. They can provide reasoning, draw conclusions from available information, and formulate hypotheses (Harland, 2003). These learning activities are also consistent with constructivism theory, which posits that students construct their own knowledge. According to this theory, knowledge formation occurs through the integration of existing knowledge with new information. It emphasizes that knowledge is not solely acquired through a transfer process from teacher to student; rather, students must be mentally active in constructing their knowledge based on their cognitive structures. Therefore, the implementation of SBL-QGIS encourages students to actively build knowledge and develop thinking skills.

The significant impact of SBL-QGIS may be attributed to several contributing factors. *Firstly,* this learning approach actively involves students in spatially identifying problems and formulating arguments. By digitally observing physical and social phenomena in their surroundings using various open sources and mapping tools like QGIS, students are prompted to articulate problem statements based on their observations. *Secondly*, SBL-QGIS engages students in the process of data collection and processing, allowing them to convert raw data into easily understandable formats such as tables. Moreover, it cultivates information literacy skills, empowering students to differentiate between credible and unreliable sources, evaluate biases, and assess the quality of information, thereby fostering problem-solving and decision-making capabilities as they seek answers to formulated questions. *Thirdly*, SBL-QGIS facilitates student engagement in data analysis, discussion, and conclusion drawing. Through analyzing spatially analyzed data with the support of QGIS mapping, participating in discussions surrounding data analysis results, and drawing conclusions as the final step, students undergo a learning experience that enhances and refines their critical thinking abilities.

Meanwhile, students in the control group did not engage in the same learning experience. Instead, they were exposed to relatively traditional learning methods, such as lectures, discussions, question-answer sessions, and assignments, primarily focused on understanding the material being taught. They lacked the intellectual guidance and hands-on experience provided by SBL-QGIS, which would have supported them in formulating problems, processing and analyzing data, drawing conclusions, and reflecting on their learning process.

The implications of the research findings are: (1) Geography departments can consider incorporating spatial-based learning with QGIS into the curriculum to help improve students' critical thinking skills. (2) Development of more structured and comprehensive teaching modules that utilize QGIS as a tool for teaching critical thinking skills. (3) Training on the implementation of spatial-based learning with QGIS for teachers and lecturers, including the technical use of QGIS and effective teaching strategies to improve critical thinking skills. (4) Improving the quality of research in the field of spatial-based learning and its use in developing critical thinking skills.

Conclusion

In geography education, there is a pressing need for teaching methodologies that equip students with 21st-century skills essential for navigating complex social challenges. Our research highlights the importance of developing a spatial learning model to enhance students' critical thinking skills. Through our experimental investigation, we aim to enrich students' learning experiences by fostering critical thinking skills using SBL-QGIS. Introduced in 2017, this innovative model is well-suited to the demands of geography learning strategy. It comprises eight stages-spatial orientation, spatial problem formulation, data collection, organization of spatial data, spatial data analysis, drawing conclusions, communication, and reflection. We implemented this model in two parallel classes within the Geography Study Program at the State University of Malang, employing a pretest-posttest group design.

The data analysis highlights the profound impact of SBL-QGIS on critical thinking skills. Its utilization has demonstrated a notable enhancement in students' critical thinking skills, surpassing those who undergo traditional learning strategy. This model fosters advancements in recognizing spatial issues, formulating them, managing spatial data, analyzing it, and presenting arguments rooted in their analyses. However, the model developed is not suitable for teaching all geography material. Materials related to regionalism or related to the regionalism of a phenomenon will be relevant to be taught using the model of this research. The enhancement of cognitive capabilities aligns directly with the enrichment of critical thinking skills, presenting promising prospects for geography students and educators.

Implication

The implications of the impact of SBL-QGIS on various aspects of learning such as problem-solving skills, creativity, and collaboration. In addition, it becomes a policy in formulating educational goals that support integrating technology into the learning process, especially in developing students' critical thinking skills.

Recommendation

The study findings suggest that geography instructors should evaluate students' critical thinking proficiencies. Additionally, it is advisable for them to incorporate SBL-QGIS due to its proven effectiveness in enhancing critical thinking capacities. Furthermore, the integration of geospatial technologies into open-source applications and software should be considered for inclusion in the educational curriculum.

Study Limitations

This research exclusively focuses on critical thinking skills using six indicators. It also does not delve into external factors beyond the classroom environment that might potentially affect critical thinking abilities. The study lasted one month for both the experimental and control groups and was limited to the Geography Education Study Program at FIS UM. Future researchers are encouraged to explore various spatial technologies used in modeling SBL-QGIS to improve critical thinking skills. This research concludes that there is a significant impact of SBL-QGIS on critical thinking skills. Its use significantly improves students' critical thinking skills, outperforming students who use traditional learning strategies. This model encourages progress in identifying and formulating spatial problems, managing, and analyzing spatial data, and presenting arguments based on the analysis.

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