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SOPHISTICATED THINKING BLENDED LABORATORY FOR INCREASING PHYSICS EDUCATION STUDENTS' UNDERSTANDING OF GIS

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ABSTRACT

GIS is an application for conducting partial environmental analysis using data such as satellite imagery or surveys. In using GIS, there are challenges in understanding the available features, which are very complex. Various difficulties exist in understanding GIS, so a series of activities is needed. This study aims to determine whether the Sophisticated Thinking Blended Laboratory (STB-LAB) can increase undergraduate physics education students' understanding of GIS, especially in earth and space science courses. This study uses a quasi-experimental quantitative method with a two-group pretest-posttest design. A purposive sampling technique was used to select 93 undergraduate physics education students as subjects. A paired sample t-test was conducted to test the hypothesis, followed by Cohen's D Effect Size test to provide details on the increase or decrease in the average gain. This research concludes that the STB-LAB model can increase undergraduate physics education students' understanding of the use of GIS. In Cohen's D Effect Size test, the results were 1,226 when using the STB-LAB model; in other words, the average difference obtained had a strong effect. The increase focuses on the verification and communication stages, which are crucial in strengthening understanding of the use of GIS. The unexpected finding in this research is that women are better at memorizing than men, while men are better at carrying out complex sequences to understand GIS applications. This study's findings show that using the STB-LAB model can help physics education students better understand GIS.

Keywords: GIS; earth and space course; sophisticated thinking blended laboratory; understanding the use of GIS

INTRODUCTION

GIS is one of the applications of technology to find out and analyze the surrounding environment using data from various sources, which usually will produce output in the form of maps (Franch-Pardo et al., 2020). GIS was introduced to make it easier for researchers to analyze an area and present it as a map, where the map has a variety of helpful information for certain institutions or communities (Kerski, 2015). There are many methods for obtaining and processing data for GIS: surveys, direct observation, and satellite imagery (Höhnle et al., 2016). Sometimes, students are unfamiliar with GIS or processing satellite imagery data. The findings by several researchers show that students have to deal with an extraordinarily complex understanding of the flow of data processing in GIS (Mulya & Astri, 2021). Students must understand a problem and how it can be analyzed based on satellite imagery data. In addition, students must explain the features used, so they are sometimes overwhelmed when understanding GIS (Bearman et al., 2016).

According to Picchio et al. (2019), the use of GIS is better than just simple observations such

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as using the Global Positioning System (GPS) or Global Navigation Satellite System (GNSS). It is difficult for people to analyze deeply with only the results of GPS or GNSS. GIS can do further analysis than just describing the results of GPS/GNSS. GIS can integrate data findings, such as GPS/GNSS with remote sensing, to provide more in-depth information. Compared to relying only on GPS, GNSS, or Remote Sensing, Frentzos et al. (2020) stated that GIS is important because it integrates and analyzes various data sources to provide comprehensive insights that individual technologies cannot provide alone. GIS functions as a platform to combine spatial data from various sources, including GPS, GNSS, and Remote Sensing. GPS and GNSS can provide accurate location data, and remote sensing can offer detailed imagery and environmental observations, but GIS can synthesize these data sets to identify patterns, trends, and relationships. For example, GIS can overlay GNSS-collected field data with satellite imagery to analyze environmental changes or assess disaster risk in a particular area (Agustina et al., 2023).

Understanding the use of GIS is crucial for undergraduate students in physics education (Jant et al., 2020), particularly in earth and space science lectures, because GIS is a powerful tool for analyzing and visualizing spatial data. Earth and space science lectures often deal with inherently spatial phenomena, such as tectonic plate movements, weather patterns, and celestial mapping. GIS enables students to integrate various datasets, perform spatial analyses, and visualize complex relationships that are otherwise difficult to comprehend (Berendsen et al., 2023). For example, using GIS, students can overlay seismic activity maps with geological fault lines to better understand earthquake dynamics or analyze the pluvial and fluvial flood factors in practical ways. Using GIS experience with technology such as QGIS or Esri ArcGIS deepens students' conceptual understanding and equips them with practical skills relevant to research and education, especially in mitigation.

Based on the literature, some university students do not adequately understand the use of GIS. The lack of understanding of the use of GIS is seen in complex applications where students must be provided with good instructions. Sumari et al. (2018) explained that using GIS in education should be accompanied by clear and directed instructions to avoid confusion. In addition, Seremet (2013) explained that undergraduate students' understanding of GIS requires the proper steps to form because written manuals sometimes do not help them understand.

This research continued with a preliminary study on fifth-semester students of the physics education program of the 2021/2022 odd-semester academic year in the earth and space science course. In this course, students were first introduced to GIS and remote sensing to analyze the environment and disasters. The preliminary study found that 60% of the 64 students felt they did not master the use of GIS, and the result was also supported by the average GIS mastery score of 57.2, classified as low per the provisions of the physics education program at UIN Sunan Gunung Djati Bandung. Interviews with several students were also conducted. Students revealed that their lack of understanding of the use of GIS came from inadequate laboratory activity models. Sometimes, students understand GIS by searching independently, which is at risk of misconceptions. In addition, students expressed the need for a comprehensive laboratory activity model to form an understanding so that they can understand GIS in a guided manner.

Egiebor and Foster (2019) found that the use of GIS in data analysis is still relatively low. There are still many students who are still confused about using GIS features. Apart from that, Rane et al. (2020) also found that students relied on manuals and were not independent, so when tested on GIS, they would get confused due to insufficient training. Priestnall et al. (2019) also discovered that giving a manual alone did not make students understand the correct GIS analysis for a problem, so when given a particular case, students would have difficulty determining GIS analysis.

A laboratory activity model is undoubtedly one of the main pillars in forming students' understanding of the use of an application to its analysis. The laboratory activity model must be appropriate based on the subject. According to Shahzad (2021), the learning process to understand a subject is determined based on the right learning model. Whether learning uses classes or laboratories, this must be adjusted to fulfill learning objectives properly. In addition, the learning model in laboratory activities is crucial because all activities are determined by the model used (Cronin, 2017; Gumilar & Ismail, 2021; Malik & Ubaidillah, 2021).

Many models of laboratory activities can be used, starting from the Cookbook Laboratory, Inquiry Laboratory, Problem-Based Laboratory (PBL), Higher-order Thinking Laboratory

(HOT-LAB), and Sophisticated Thinking Blended Laboratory (STB-LAB). Based on their use, the Cookbook Laboratory is too instructional, so students are not too independent in understanding. Cookbook Laboratory provides minimal experience in understanding, so students only know the instructions without forming an understanding (Rokos & Zavodska, 2020). In addition, Cookbook Laboratory only allows students to reproduce from previous experiments; in other words, it will make students become robots (Fadaei, 2021). Inquiry Laboratory and Problem-Based Laboratory (PBL). These models seem related, but inquiry and PBL tend not to give students the freedom to think. A problem in the inquiry laboratory and PBL must be answered according to those who designed them (Potkonjak et al., 2016; Ural, 2016). Inquiry laboratory and PBL only focus on students' basic understanding of concepts and not on a thorough and in-depth understanding (Amir et al., 2020). Fitriana (2017) explained that laboratory inquiry did not significantly increase the understanding of a concept. Only in certain aspects did it increase because the inquiry laboratory only focused on elaborating concepts, not understanding a concept. In addition, Saharsa et al. (2018) also explained that PBL did not increase significantly in terms of understanding and applying physics concepts. PBL focuses on a problem and understands it, so it requires understanding the previous concept, regardless of whether students' understanding of concepts increases or not.

Inquiry laboratory and PBL were updated with the Higher-order Thinking Laboratory (HOT-LAB). HOT-LAB model has three main syntaxes: (1) Pre-Lab, (2) Lab, and (3) Communication (Malik et al., 2017). HOT-LAB has a fairly good framework for forming an understanding. However, it tends to rely on students' independence, so sometimes they feel less guided and do not know whether what they understand is correct (Setya et al., 2021). The latest laboratory activities model is the Sophisticated Thinking Blended Laboratory (STB-LAB). STB-LAB has five main syntaxes: (1) Disposition, (2) Argumentation, (3) Verification, (4) Lab, and (5) Communication (Agustina et al., 2022). STB-LAB prioritizes students' understanding because it uses persuasive axiology, where students will independently be assisted in verifying their findings to maximize their understanding (Agustina & Putra, 2022).

Ridha et al. (2020) stated that providing education about GIS is necessary. There must be a special learning design for studying GIS, such as problem-based learning, to improve students' spatial thinking. In addition, Kerski and Baker (2019) found that digital portfolio models make it possible to improve problem-solving skills in using GIS. Anunti et al. (2020) stated that the project-based learning model could improve students' problem-solving skills.

Various studies on the use of GIS have been carried out by other researchers, such as Jo and Hong (2020), who used GIS to understand spatial concepts, showing a better understanding of the subjects with good spatial skills. Healy and Walshe (2020) stated that, in understanding spatial concepts, more attention must be paid to spatial basics, which can be achieved through the skilled use of GIS. There are various studies on increasing the use of GIS, such as Jant et al. (2020), who prioritized the use of STEM in measuring skills in using GIS, with the results obtained that students can understand the steps for using GIS. Schulze (2021) found that students tend to understand the use of GIS if there are instructions, while students do not know what they are doing and the function of the features used in using GIS. Thus, Buzo-Sanchez et al. (2022) emphasize that students trained in spatial skills or using GIS can analyze based on their understanding without following instructions. This understanding can be achieved by emphasizing the basic understanding of a concept or application (Bauer, 2021; Irfan et al., 2020; Weichold, 2020).

Previous findings regarding the use of learning models in GIS-based learning activities only focus on high-level skills, but low-level skills are not paid attention to. According to Hanif (2019), high-level skills will be quickly improved if students already understand the basics of science or technique. Therefore, it is crucial to use the right learning model to provide a basic understanding of GIS and make it easier for students to understand high-level skills. Regarding students' understanding of GIS using the STB-LAB model, further research is needed to learn more about the STB-LAB.

Based on the preliminary study, it is imperative to analyze the understanding of GIS when using appropriate laboratory activity models. This study aims to determine whether the STB-LAB model can shape physics education students' understanding of GIS. This study focuses on STB-LAB models that are often used in educational majors. Physics education students were chosen because mitigation is often taught so that prospective teachers can teach more efficiently about mitigation. Due to limitations, this research focuses on low-level skills.

METHODS

This study uses a quasi-experimental quantitative method with a two-group pretest-posttest design. This research is a class action study, compared between groups that used class action and those that did not. The research design is presented in Table 1.

Table 1. Two Group Pretest-Posttest Design

Group	Sampling	Pretest	Treatment	Posttest
Control	Purposive	P_{1a}	-	P_{2a}
Experiment		P_{1b}	T	P_{2b}

(Bazaz et al., 2018)

The groups used a control group and an experimental group. P_{1a} stands for the pretest in the control group, P_{2a} stands for the posttest in the control group, P_{1b} stands for the pretest in the experimental group, T stands for the treatment (STB-LAB), and P_{2a} stands for the posttest in the experimental group. The population used in this study is fifth-semester students of the 2022/2023 academic year. Subjects were determined using a purposive technique with the following criteria: (1) In the fifth semester; (2) Taking earth and space science courses (3) Attended three previous meetings. Ninety-three students were subjects of this study. The entire sample was divided into the control and experimental groups. The subjects are described in Table 2.

Table 2. Descriptions of Research Subjects

Group	Gender		Total
	Male	Female	
Control	22	24	46
Experiment	21	26	47

In practice, the control group was pretested first. The control group learned about GIS without using the STB-LAB model, and then, a posttest was conducted to find the final result. The treatment group underwent the same process with a different treatment; they learned using the STB-LAB model. The material used in both groups is the Urban Heat Island material by correlating Land Surface Temperature (LST) to the Normalized Difference Vegetation Index (NDVI).

Skills and understanding of the use of GIS were assessed with a Likert scale of 1-5. The assessment instrument was adapted based on indicators of understanding from several previous researchers (Table 3).

Table 3. Assessment Instruments and Indicators

Indicators	Source	Description
Restatement	Nurani et al. (2021)	How students restate GIS concepts based on the problems they face
Classification	Trianggono (2017)	How students classify the features used in analyzing data in GIS
Explanation	Riwanto et al. (2019)	How students explain the features used in GIS and their functions
Presentation	Abdi et al. (2021)	How students present examples of the use of features used in GIS
Use	Ramadani and Nana (2020)	How students' skills in using GIS features in analyzing data
Proof	Hidayat et al. (2022) and Hoernig and Seasons (2017)	How students prove that the features used are appropriate based on various references

All assessments were conducted after carrying out a series of laboratory activities for two meetings, and the assessment after the treatment (posttest) was analyzed together with the pretest results. Before the pretest, students were notified of the use of GIS in the Urban Heat Island laboratory activities, so students looked for references to the use of GIS.

After all the data were correctly and completely obtained, a classic assumption test was carried out before a hypothesis test. The classic assumption test includes a normality test and a homogeneity test.

The normality test in this study used the Kolmogorov-Smirnov (K-S) normality test because the number of subjects used was above 35 samples (Mishra et al., 2019). K-S test is recommended if the sample is more than 35 because it tests the distribution of data continuously so that decisions are made based on populations that have been specifically distributed (Wu & Leung, 2017). The decision on the normality test using the K-S test will be fulfilled, or the data is normally distributed if the Significance value is above 0.05 (Sig. > 0.05) (Purnama et al., 2021). This normality test is important because the decision to take the next hypothesis test can be determined by the type of use of the test and whether the data is normally distributed (Das & Imon, 2016; Hanusz & Tarasińska, 2015). The homogeneity test was conducted using Levene's test. The homogeneity test is not considered an absolute requirement, but the homogeneity test is better done if there are differences in the number of samples used between sample groups (Listiawati et al., 2022). Levene's test can determine the magnitude of the variance between two or more data used as a group so that the data between groups can be declared equivalent without excessive discrepancies in values (Wang et al., 2017).

After the classic assumption tests, the hypothesis test was carried out to determine the hypothesis decided in this study. It was carried out by looking at the normality of the data. If the data is normally distributed, then the hypothesis test will be carried out using the t-test; if the data is not, the Wilcoxon test is carried out. The t-test and the Wilcoxon test aim to look at the results of comparing the average data acquisition from the two groups. However, the t-test will be very optimal and accurate if the data is normal, but vice versa if the data used is not normal. On the other hand, the hypothesis test will be more optimal and accurate when using the Wilcoxon test (Szucs & Ioannidis, 2017). The hypothesis of this research is presented in Table 4.

Table 4. Research Hypothesis

Decision	Description
Sig. < 0.05	Accept H_0 Reject H_a, Effective to increase understanding of GIS after using the STB-LAB laboratory activity model
Sig. > 0.05	Reject H_0 Accept H_a, Less Effective to increase understanding of GIS after using the STB-LAB laboratory activity model

To provide an overview of the increase or decrease in understanding of GIS in this study, an effect size test was carried out to determine the magnitude of the effect that affects treatment. The effect size test used in this study is Cohen's D Effect Size, which compares the two groups. Cohen's D Effect Size uses the subtraction of the average values of the two groups divided by the standard deviation of the two groups used, and then the results can be divided by 10 to get results according to interpretation (Kraft, 2020; Wisniewski et al., 2020). The Cohen's D Effect size test results are interpreted in Table 5.

Table 5. Cohen's D Effect Size

Cohen's D	Interpretation
0 – 0.2	Weak Effect
0.21 – 0.50	Moderate Effect
0.51 – 0.80	Strong Effect
0.81 – 1.20	Very Strong Effect

All statistical tests were processed with the IBM SPPS Statistics 26.0 application. This research was conducted from October – December 2022 (Quartile 4).

RESULTS AND DISCUSSION

The pretest and posttest results were obtained from 93 subjects sampled and divided into the control and experimental groups. The scores were averaged to display the research results. The average pretest and posttest scores of the two groups are displayed in Table 6.

Table 6. Average Pretest and Posttest Scores of Research Groups

Group	Gender				Total	
	Male		Female			
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Control	28.045	60.291	28.125	61.318	28.395	61.041
Experimental	29.523	82.380	29.230	81.230	29.461	81.711

Based on Table 6, the posttest results of the experimental group were greater than those of the control group, with a difference of 20.670. The difference in pretest scores was 1.066. The highest posttest score in the experimental group based on gender was 82.380 by male students. This score was 1,150 points higher than the female students, with a posttest score of 81.230. In addition, in the control group, the male students also received a higher posttest score (61.318), 1.027 points higher than the female students (60.291).

The normality and homogeneity tests were performed after obtaining and describing the data to be tested further. The normality test results are presented in Table 7.

Table 7. Normality Test

Group	Type	Kolmogorov-Smirnov		
		Statistic	df	Sig.
Control	Pretest	.128	46	.055
	Posttest	.116	46	.147
Experimental	Pretest	.123	47	.072
	Posttest	.114	47	.164

Based on Table 7, all normality tests obtained in both groups are normal in both pretest and posttest types. The normal value is shown in the control group's pretest (.055), the control group's posttest (.147), the experimental group's pretest (.072), and the experimental group's posttest (.164). All Sig. > 0.05 means the data is normal (Yang et al., 2018). Furthermore, the homogeneity test with Levene's test was carried out because the two groups had different subjects, so it is necessary to know the homogeneity of the data. The homogeneity test results are presented in Table 8.

Table 8. Homogeneity Test

Test of Homogeneity of Variance				
	Levene Statistic	df1	df2	Sig.
Based on Mean	.389	1	91	.535
Based on Median	.235	1	91	.629
Based on Median and with adjusted df	.235	1	90.889	.629
Based on trimmed mean	.340	1	91	.561

Based on Table 8, the data is homogeneous, showing the Sig Based on the Mean has a value of .535, thus Sig > 0.05, meaning that the decisions made are homogeneous data (Kim & Cribbie, 2018). After the data used was decided to be normal and homogeneous, the hypothesis test was carried out using the t-test. The t-test was carried out using the paired sample t-test method, and comparisons were made on the pretest and posttest of understanding GIS in each group. A different group code was assigned to each group. The results of the independent sample t-test are displayed in Table 9.

Table 9. Paired Sample T-Test

Type	Mean	Std.Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Control	32.500	8.552	1.261	35.040	29.960	25.773	45	.000
Experiment	52.383	5.784	.844	54.081	50.685	62.085	45	.000

Table 9 shows that the two groups get Sig. (2-tailed) of .000, in which both groups get an increase in understanding of the use of GIS applications. This decision was taken based on some literature which states that if the Significance value on the paired sample t-test gets the results above or below 0.05, then the decision taken is to accept H0, reject Ha, or in other words, there is a difference in the average value between the two values being observed (Javaid et al., 2016; Li et al., 2020).

Furthermore, an analysis was carried out to determine the magnitude of the effect on the treatment used in both groups using the Cohen's D Effect Size test to determine the increase in the two groups. The Cohen's D Effect Size test results, which provided details of the increase in the two groups, are displayed in Table 10.

Table 10. Cohen's D Effect Size Test

Group	Mean	Std. Dev	Cohen's D Effect Size
Control	32.500	8.552	0.620
Experiment	52.383	5.784	1.022

Table 10 shows that Cohen's D value for the experimental group is greater than the control group. The experimental group obtained a Cohen's D value of 1.022, while the control group obtained 0.620. These results show that the control group gets a strong effect, while the experimental group gets a very strong one.

The findings in the control group indicated that descriptively, the gain in understanding the use of GIS in the female students was 0.08 greater than that of the male students in the pretest. The female students in the posttest were also superior to the males, with a difference in the score of understanding GIS of 1.027. However, the experimental group showed that the male students were superior in understanding the use of GIS in the pretest and posttest, with a difference of 0.223 in the pretest and 1.150 in the posttest.

In the descriptive findings, based on gender in both the control and experimental groups, it is known that female students prefer memorization rather than complex things. Male students appear superior in complex things, which is based on the fact that they are more stimulated by understanding a series of complex activities. Male students tend to prioritize logic compared to female students. According to previous research, men tend to be stimulated by complex activities to turn off their interest in understanding or applying a concept (Risman, 2018). On the other hand, women understand a concept simply by memorizing it because they tend to be overwhelmed when following complex sequences. Women tend to use the hippocampus part of the brain, connecting new information with their emotions (Gershman, 2017). The emotional state of women also affects memory processing in understanding because the hippocampus in women connects more with emotional states. When a woman's emotional state is terrible, they will also be deficient in processing memory in understanding things (Bayer et al., 2018; Geib et al., 2017). However, this study was not too deep because this research focuses on the treatment of the STB-LAB method for understanding the use of GIS at the undergraduate level, especially in the physics education department, so the description of gender is only an additional finding.

The hypothesis test shows that the two groups have an average difference and how much effect the average difference is on the Cohen's D Effect Size test. The effect size is 0.620 in the control group, which has a strong effect, and 1.226 in the experimental group, which has a very strong effect. These results show that STB-LAB can improve undergraduate physics education students' understanding of using GIS. This increase is based on syntax analysis in the entire complex series of STB-LAB, especially at the verification stage, where students verify with the lecturer/assistant teacher to discover the errors. Verifying helps students know where the errors are so they can easily understand or use a concept or application (Ballou & Springer, 2015). Therefore, verification is needed to correct an error when re-testing further from a laboratory activity so that students do it well and understand what they do (Ioannidis et al., 2015).

In addition, the verification stage allows students to express other alternatives when conducting experiments later. It is supported by sound arguments that students are given space to express opinions according to their understanding in the argumentation stage. Determining a method or step in an experiment requires a good understanding, so understanding must be tested further to ascertain whether the understanding of the following action is appropriate. Before that, students must read many references to strengthen their understanding (Haug, 2017; Tondeur et al., 2017).

At the communication stage, the STB-LAB model provides an overview of the findings and requires students to explain again why some actions must be taken and why a method must be applied in the experiment. As a result, there will be two-way communication so that students know more about the following action. Communicating in detail is required in an experimental laboratory activity. Communication in laboratory activities to show their findings, starting from how students get data, process it, and submit their experimental reports, certainly helps students form a more profound understanding when communicating to get feedback from lecturers so students can understand what to do (Fassett & Nainby, 2017; Putra, 2022). Overall, the syntax of the laboratory and communication in STB-LAB can emphasize a deeper understanding of GIS. In the laboratory session, undergraduate students can implement their understanding of GIS when they conduct a literature review in the verification session so that they can also provide reasons for their arguments in the argumentation session. These results align with previous studies that are similar to the use of STB-LAB. Finne et al. (2022) and La Braca and Kalman (2021) stated that the observation or implementation stage in laboratory activities can certainly make undergraduate students better understand the concept and use and provide direct experience. Integrating the disposition session into argumentation also has an important role, because undergraduate students have a basic understanding first to understand the problems given, provide their arguments, and look for facts about the problems. Undergraduate students conduct laboratory activities to test and analyze their arguments more deeply.

Communication sessions certainly have a vital role because they provide colleagues feedback so that the application and understanding of GIS can be discussed more deeply. Halimah and Sukmayadi (2019) stated that presenting findings through good communication can provide greater understanding because what has been conveyed can be discussed more deeply by paying attention to the concept.

CONCLUSION

This research concludes that the STB-LAB model can increase undergraduate physics education students' understanding of the use of GIS. In Cohen's D Effect Size test, the results were 1,226 when using the STB-LAB model; in other words, the average difference obtained had a strong effect. The increase focuses on the verification and communication stages, which are crucial in strengthening understanding of the use of GIS. The unexpected finding in this research is that women are better at memorizing than men, while men are better at carrying out complex sequences to understand GIS applications. This study's findings show that using the STB-LAB model can help physics education students better understand GIS.

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