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Utilizing A Virtual Laboratory based on Mobile Learning: Implementation for Social Science Education Students in Indonesia to Improve Learning Outcomes

Abdul Bashith, Saiful Amin, Muhammad Aliman, Muchammad Akbar Kurniawan, Hasse Jubba, Linda Maulidiah

Research Article

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Author for correspondence:
Abdul Bashith
abbash98@pips.uin-malang.ac.id
Department of Social Science Education, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, Indonesia

Abstract

Background/purpose. Empirical data consistently demonstrate that social sciences education suffers from suboptimal learning outcomes, primarily due to overcrowded curricula and students' struggle to connect abstract theoretical concepts with real-world applications. Therefore, learning that implements technology to assist students in comprehending complex material is required so that they remain focused and understand it more easily. This study aims to evaluate the impact of utilizing a virtual laboratory based on mobile learning on the learning outcomes of students majoring in social sciences education. Furthermore, this study investigated student feedback about the utilization of this virtual laboratory based on mobile learning.

Materials/methods. This quasi-experimental study utilized a non-equivalent control group design with a pre-test and post-test. The participants in this study were 46 students of social sciences education at UIN Maulana Malik Ibrahim in Malang, Indonesia. This research employed valid ($p < 0.05$) and reliable test instruments (Cronbach's alpha = 0.746) to collect learning outcome data and utilized closed-ended question instruments to gather student responses following implementation of the TNBTS V-Lab application. The data were analyzed with descriptive and quantitative approaches using SPSS 22.0 for Windows.

Results. The research findings demonstrated that the implementation of the TNBTS V-Lab application can significantly enhanced students learning outcomes, as evidenced by a gain score increase of 37.61 points. Meanwhile, students responded very positively to the use of the TNBTS V-Lab application.

Conclusion. This study presented a comprehensive examination of the significance of virtual laboratories in the context of education. The responses of students when utilizing virtual laboratories will be explained in this article.

1. Introduction

The importance of conventional teaching in the classroom has decreased at this time. Moreover, the learning process fails to incorporate practical, real-world scenarios or contextual engagement (Gras et al., 2013), Thus, it is important to implement learning methods that stimulate genuine contextual settings for students, thus facilitating comprehension (Alekseyeva et al., 2023; Kurniawan et al., 2022). The implementation of theory and practice is facilitated by infrastructure and facilities, including laboratory facilities, which are necessary for learning activities (Amankwaa et al., 2023). Among the various types of laboratories, one is the field laboratory or natural environment.

Field laboratories offer several benefits to students, including the capacity to investigate various environmental conditions and natural processes, acquire a comprehension of the components in ecosystems, and understand natural and social phenomena that are challenging to stimulate in a controlled laboratory setting (Bashith et al., 2022; Prastiyono et al., 2021). Field laboratory is crucial in enhancing students' engagement and creativity (Handayani & Suharyanto, 2016; Kravchenko et al., 2024). Furthermore, field laboratories have the potential to serve as a teaching tool by facilitating the integration of theoretical concepts with practical experiences experienced in the field (Tejado et al., 2021; Yalcinkaya & Cinar Yucel, 2023). Field laboratories also have the potential to serve as research sites, where scientific investigation can be developed while benefiting the environment and society (Fatmaryanti et al., 2022).

At present, inviting students to visit the field laboratory remains a challenge for some lecturers and students (Bashith et al., 2022; Saputra & Kuswanto, 2019). Factors, including time and travel expenses, continue to challenge providing students with an actual field experience (Haleem et al., 2022). Therefore, implementing a virtual laboratory (V-Lab) is a crucial option to address this issue (Achuthan, 2018; Carroll et al., 2010).

Meanwhile, the implementation of mobile learning as s form of technology into the classroom significantly facilitates students' scientific comprehension. Mobile learning offers advantages, including the ability for users to access it from any location and at any time, thereby saving time (Prastiyono et al., 2023; Wijayanto et al., 2023). Integrating mobile learning technology and virtual laboratories is anticipated to improve learning outcomes, allowing students to save time and money on travel while enabling continuous and in-depth evaluation of phenomena being studied, thereby enhancing their comprehension of discovered problems (Shou, 2022; Tuysuz, 2010).

2. Literature Review

2.1. Virtual Laboratory

A virtual laboratory (V-Lab) is a simulation environment developed by technology that replicates the experience of a physical laboratory in virtual setting (Kurniawan et al., 2022). It enables users to conduct experiments, observe phenomena, and gain knowledge about diverse scientific concepts without having to be in a physical laboratory, which is particularly helpful in educational and research settings (Bashith et al., 2022). Therefore, the presence of a laboratory offers advantages in terms of time efficiency while maintaining the fundamental of education (Erdoğan & Bozkurt, 2022).

Important information that can be acquired through virtual laboratories includes: Experiment Simulation: Virtual laboratories allow users to run experiments virtually (Carroll et al., 2010; Guzmán & Joseph, 2021). Social conditions include its economic and cultural conditions, just as natural phenomena are included within social science (Hurtado-Bermúdez & Romero-Abrio, 2023). Students require a virtual laboratory in order to replicate actual conditions virtually, eliminating the need for them to physically visit the actual location (Carroll et al., 2010; Oktavianto et al., 2024). Furthermore, V-Lab facilitates access for students who live at quite a ways from their initial location (Bashith et al., 2022). Students also benefit from V-Lab's reduced costs and enhanced security (Amin et al., 2022).

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V-Lab has the capability to be transformed interactive because of the multimedia structure. V-Lab offers students the chance to customize, investigate, and project phenomena that occur in the field (Fatmaryanti et al., 2022; Prastiyono et al., 2021). Previous research similarly indicates that virtual reality implementation enhances students' cognitive abilities in social science education while fostering positive interest in volcanology subject matter (Prasetya et al., 2024). Moreover, V-Lab enables remote student collaboration for learning, experiments, and discussions (Gonzalez-Romo et al., 2023). While virtual laboratories may not consistently replicate the exact conditions of a physical laboratory, it do offer several significant advantages (Oktavianto et al., 2024).

2.2. Mobile Learning

Mobile learning, or ML, pertains to a teaching and learning strategy that utilizes portable devices, including smartphones, tablets, and similar devices, to facilitate the collection, distribution, and application of educational materials (Oyelere et al., 2018). This methodology offers individuals the flexibility to engage in studying at their convenience and in accordance with their time rules (Fang et al., 2023). Mobile learning offers students the flexibility to access and utilize it at any time and from any location (Alam & Mohanty, 2023). Mobile learning allows for the integration of a variety of multimedia, including audio, video, images, and educational activities, which enables students to engage in more interactive learning under flexible conditions (Manyilizu, 2023).

The integration of mobile learning has been crucial in transforming the teaching process through the utilization of increasingly advanced technology (Baladoh et al., 2017). This strategy continues to develop in combination with technological advancements and shifting learning requirements. It has been demonstrated that mobile learning enhances student achievement (Handayani & Suharyanto, 2016). Furthermore, the integration of science-Islam into mobile learning (Amin et al., 2022), and outdoor study integration have the potential to enhance student learning outcomes (Prastiyono et al., 2021).

Extensive research has been conducted on the topics of V-Lab and ML, providing a valuable reference for the present study. For example, in Spain, V-Lab was used for soil organic matter investigations (Gras et al., 2013). V-Lab was used by Universidad de Sevilla students to learn about electron microscopy (Hurtado-Bermúdez & Romero-Abrio, 2023), The utilization of V-Lab by the students of the Indian Institute of Technology Kharagpur India has effectively enhanced both student engagement and pedagogical competencies (Alam & Mohanty, 2023). Furthermore, students in Tanzania acquire enhanced comprehension skills in practical chemistry through the utilization of V-Lab (Manyilizu, 2023). Students with special needs in Saudi Arabia can also benefit from the increased knowledge provided by V-Lab 3D (Elfakki et al., 2023). In Slovakia, the development of V-Lab was carried out to study photogrammetric imaging (Baron et al., 2024). Students in Jordan and Russia can improve their natural science literacy through the use of V-Lab (Alekseyeva et al., 2023; Shudayfat & Alsalhi, 2023), V-Lab technology also helps in the learning of neurosurgical anatomy at Barrow Neurological Institute in Arizona, USA (Gonzalez-Romo et al., 2023), V-Lab development has also improved the cognitive, self-confidence, and independence of forensic science students at Northumbria University in England (Amankwaa et al., 2023).

2.3. Social Science Education

Contemporary research emphasizes the significance of sustainable social science education in developing crucial 21st-century skills (Moreno, 2022). Studies indicate that integrating sustainability concepts into social science curricula enhances global awareness, critical thinking, and problem-solving abilities (Caniglia et al., 2018). Interdisciplinary approaches and the incorporation of sustainable development goals (SDGs) have been shown to provide a more comprehensive understanding of complex social and environmental issues (Lozano et al., 2019).

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Implementation of sustainable social science education has demonstrated positive effects on student engagement and learning outcomes (Hallinger & Nguyen, 2020). Research suggests that community-based projects, innovative technologies, and novel teaching methods can improve learning motivation, practical application of knowledge, and global consciousness (Brundiers et al., 2021; Caniglia et al., 2018). Additionally, institutional leadership plays a vital role in effectively integrating sustainability principles into social science curricula (Lim et al., 2022).

Recent studies highlight the importance of experiential learning and real-world applications in sustainable social science education (Dlouhá & Pospíšilová, 2018; Vare et al., 2019). Solution-oriented sustainability learning, place-based education, and systems thinking have been found to enhance students' competencies in addressing complex sustainability challenges (Odell et al., 2020). Researchers advocate for transdisciplinary approaches to bridge the gap between academic knowledge and societal needs, emphasizing critical reflection, dialogue, and action to foster deep learning and personal growth (Sterling & Rieckmann, 2016). This study extends previous research in sustainable education that primarily focused on student engagement in social and economic aspects (Caniglia et al., 2018). Our research takes a more comprehensive approach by simultaneously incorporating environmental, social, and local historical dimensions, specifically targeting social sciences in Indonesia within the Indonesian context.

Diverse researchers have also contributed to the development of mobile learning research. Although medical (Fang et al., 2023), nursing (Yalcinkaya & Cinar Yucel, 2023), pharmacy (Kurowsky, 2023), electronic goods recycling (Senthilselvi et al., 2020), junior high school (Prasetya et al., 2024), software algorithms (Bayar & Hambarci, 2023), hearing-impaired students (Baladoh et al., 2017), matter on processes soil organic (Gras et al., 2013), have all been discussed, researchers have given little interest in the application and development of mobile learning and virtual laboratories for social sciences students. Similarly, there has been considerable research on Augmented Reality, Educational Technology, mobile learning, blended learning, and online learning during COVID-19 in higher education. However, among these studies, few have involved various components in an integrated manner. Therefore, this research aims to comprehensively integrate mobile learning applications with virtual reality, specifically for Social Studies students. Additionally, we endeavoured to formulate a conceptual model for virtual reality application development specifically designed for social studies students. The purpose of this study is to assess the effectiveness of mobile learning-based virtual learning for Social Studies students in Indonesia. The following hypotheses can be proposed based on the background and theoretical framework presented above.

H0 : There is no difference in student learning outcomes before and after using mobile learning based field laboratory in learning.

H1 : There is a significant difference in learning outcomes between students who use mobile learning in field laboratory compared to students who use traditional learning methods.

3. Methodology

3.1. Research subject

The research described in this article used a quasi-experimental design, specifically a pre-test and post-test non-equivalent control group design. The research class selection employed convenience sampling technique due to the pre-established classroom availability and enhanced practicality of the research implementation process (Shadish et al., 2002). Meanwhile, the variable "achieved" represents the learning outcomes of students in the field of social studies. Due to the quasi-experimental aspect of this research, researchers are unable to retain perfect control over the two groups being evaluated. As a result, the observed changes cannot be solely attributed to the

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influence of the treatment. The research used a pre-test-post-test control group design, which is a type of quasi-experimental design. This design is illustrated in Table 1.

Table 1. Pre-test – Post-test Control Group Design

Groups	Pre-test	Treatment	Posting
Experimental	O_1	X	O_2
Control	O_3	-	O_4

Source: (Campbell & Stanley, 1967)

Description

O_1 : *Pre-test* for experimental group
O_2 : *Posttest* for experimental group
X : Learning with virtual laboratories in experimental group
O_3 : *Pre-test* for control group
O_4 : *Posttest* for control group
\- : Learning without virtual laboratories in control group

Students studying in the Social Sciences Education Department at UIN Maulana Malik Ibrahim Malang, located in East Java, Indonesia, served as the subjects of the experimental research. The students were in 5th semester of the 2023/2024 academic year is examining the economic behaviour of communities on the slopes of Mount Tengger for the Material Development and Social Studies Learning Methodology course. Two experts from research teams and an expertise team, both of which were financially supported by the Litapdimas Ministry of Religion in 2023, are delivering this course. Four classes of students are participating in this course. The method used to select subjects was purposive sampling; subjects were selected with same cognitive ability characteristics, as determined by the mean value of learning outcomes. Then, two groups, one experimental and one control, were obtained. The number of students who participated in the research is detailed in the following Table 2.

Table 2. Research Subject

No	Group	Gender		Total
		Female	Male	
1	Experimental	18	5	23
2	Control	19	4	23

3.2. Research Limitation

This study has an extensive reach as it involves students in their fifth semester from the Social Science Department at UIN Maulana Malik Ibrahim Malang, Indonesia. Therefore, this study has limitations to keep its focus on the research subject. This study only evaluated two out of the four classrooms of students in 5th semester at Social Science Education. Furthermore, this study is limited by the group size, with each classroom consisting only of 23 students. The duration of the research session for implementing learning in both the experimental group and control group is three meetings. Learning is conducted for 110 minutes in each meeting. This study can serve as fundamental research and an example for other developmental research conducted in other countries.

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3.3. Implementation

While implementing research into the classroom, the researchers used two learning models, specifically the conventional learning model and the exploratory learning model with V-Lab Mobile Learning about Bromo Tengger Semeru National Park (further in this article it is referred as V-Lab ML TNBTS). Two classes of students were chosen through purposive sampling technique to serve as an experimental group and a control group. The research methodology used in the experimental group can be seen in the following figures: 1.

Figure 1. A) The lecturer explains the learning achievements, B) The lecturer explains the use of V-Lab ML TNBTS, C) Students install V-Lab ML TNBTS, D) Students use V-Lab ML TNBTS.

The figure illustrated the students' interest in following the lecturer's instructions on utilizing V-Lab ML TNBTS. The learning was conducted in three meetings. During Meeting 1, students were administered a pre-test to assess their initial comprehension of the topic of Economic Behaviour of the Mount Tengger Slope Community. After that, the lecturer provided a comprehensive overview of the subject, specifically focusing on the Economic Behaviour of the Mount Tengger Slope Community. During Meeting 2, students were encouraged to install V-Lab ML TNBTS on their mobile devices and were given instructions on how to use it. During meeting 3, students examined the content inside the V-Lab ML TNBTS application. Following that, students take a post-test using the V-Lab ML TNBTS application to evaluate their comprehension of the Economic Behaviour of the Mount Tengger Slope Community. Meanwhile, the learning activities conducted in the control group can be seen in the following figure 2.

Figure 2. A). The lecturer explains the learning outcomes, B) The lecturer provides an explanation regarding the topic using explanatory techniques, C) Students create groups to present discussion, D) Students present the results of the discussion in front of the class.

The figure above indicated that the control group employed a conventional learning model to discuss about the Economic Behaviour of the Mount Tengger Slope Community. The learning was conducted in three meetings. During Meeting 1, the lecturer began by administering a pre-test and then proceeded to provide a comprehensive presentation on the subject. Further, at meetings 2 and 3, students delivered presentations on the outcomes of their group discussions in front of the classroom. Furthermore, a post-test was administered at the end of the 3rd meeting. A post-test was conducted to evaluate students' comprehension of the subject related to the Economic Behaviour of the Mount Tengger Slope Community.

3.4. Research Instrument

The variable examined in this study is the constant variable represented by the implementation of Virtual Laboratory media using mobile learning at Bromo Tengger Semeru National Park (V-Lab ML TNBTS). Meanwhile, the variable that is not influenced by other factors is the effect of student

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learning about the Economic Behaviour of the Mount Tengger Slope Community. The tool utilized to evaluate student learning results is written tests. The essay is structured with a format that includes 5 questions. The test questions related to the learning indicators for the subject on the Economic Behaviour of the Mount Tengger Slope Community. Prior to data collection, the test questions passed validity testing using the product moment correlation technique, and their reliability was assessed using Cronbach's Alpha (Campbell & Stanley, 1967). Before the learning process, students were provided with the research instrument. The duration required for students to respond to these 5 questions was 30 minutes. Students in both the control and experimental groups completed these questions using the Google Form, starting with providing their personal information. Following the administration of a pre-test to students, learning was conducted during three sessions. In the 3rd meeting, students were given the same questions as a post-test to assess the learning outcomes of the topic on the Economic Behaviour of the Mount Tengger Slope Community. The following essay questions serve as both a pre-test and post-test. See Table 3.

Table 3. Test Instrument for Student Learning Outcome

No	Questions
1	Explain the development scope of Social Sciences teaching materials related to the topic of Economic Behavior of the Mount Tengger Slope Community.
2	Explain the fundamental concepts of economics as a subfield of Social Sciences and how to apply them to economic activities in daily life of the Mount Tengger Slope Community?
3	Explain the fundamental concepts of geography as a subfield of the Social Sciences and how to develop the scientific application in daily life of the Mount Tengger Slope Community?
4	Explain the fundamental concepts of sociology as a subfield of Social Sciences and how to apply them in daily life of the Mount Tengger Slope Community?
5	Explain the fundamental concepts of history as a subfield of the Social Sciences and how to develop the scientific application in daily life of the Mount Tengger Slope Community?

This instrument was tested on social sciences students who had previously completed this course. The criteria for Cronbach's alpha reliability can be seen in the following table 4:

Table 4. Cronbach Alpha Criteria

No	Cronbach alfa	Category
1	$\alpha \geq 0.9$	Very highly reliable
2	$0.8 \leq \alpha < 0.9$	Highly reliable
3	$0.7 \leq \alpha < 0.8$	Reliable
4	$0.6 \leq \alpha < 0.7$	Marginally / minimal reliable
5	$\alpha < 0.6$	Unacceptably low reliability

Source: (Taber, 2018)

Further information regarding the instrument validity test findings can be found in Table 5.

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Table 5. Validity Test of Essay Instruments

		Q_1	Q _2	Q _3	Q _4	Q _5	Total
Q_1	Pearson Correlation	1	.197	.462*	-.022	.397	.574*
	Sig. (2-tailed)		.420	.047	.930	.093	.010
	N	19	19	19	19	19	19
Q_2	Pearson Correlation	.197	1	.435	.337	.673**	.745**
	Sig. (2-tailed)	.420		.062	.158	.002	.000
	N	19	19	19	19	19	19
Q_3	Pearson Correlation	.462*	.435	1	.472*	.513*	.786**
	Sig. (2-tailed)	.047	.062		.041	.025	.000
	N	19	19	19	19	19	19
Q_4	Pearson Correlation	-.022	.337	.472*	1	.394	.616**
	Sig. (2-tailed)	.930	.158	.041		.095	.005
	N	19	19	19	19	19	19
Q_5	Pearson Correlation	.397	.673**	.513*	.394	1	.843**
	Sig. (2-tailed)	.093	.002	.025	.095		.000
	N	19	19	19	19	19	19
Total	Pearson Correlation	.574*	.745**	.786**	.616**	.843**	1
	Sig. (2-tailed)	.010	.000	.000	.005	.000	
	N	19	19	19	19	19	19

Table 5 demonstrated that the instrument validity test, conducted using the product moment correlation technique, confirms the validity of the 5 questions. This is evidenced that each Sig. value (2-tailed) < < α 0,05. Hence, this essay questionnaire instrument can be used to evaluate the learning outcomes of social sciences students on the subject of Economic Behaviour of the Mount Tengger Slope Community. Following that, the essay question instrument received another test to evaluate the consistency of the informants' responses to the questions they responded. See the reliability test results Table 6 for more details.

Table 6. Reliability Test of Essay Instruments

Cronbach's Alpha	N of Items
.746	5

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Table 6 indicated that the Cronbach alpha value is 0.746, implying that the essay question instrument has a fairly high level of reliability. This instrument is highly effective for assessing the social sciences student learning outcomes related to the Economic Behaviour of the Mount Tengger Slope Community. To assess student responses regarding the implementation of the TNBTS V-Lab application, we administered a structured questionnaire utilizing a Likert scale, which incorporated the following indicators and corresponding question items:

Table 7. Student responses to the content and pedagogical quality of the TNBTS V-Lab application

No	Indicators	Question Item
1	Content Validity and Scope	The scope of Social Studies topics
2		The depth of Social Studies topics
3		Factual accuracy
4		The accuracy of a theory or concept
5	Conceptual Coherence	The rationale of the concept
6		The disintegration of a concept
7		The fundamental truth
8		Procedures/methods accuracy
9	Relevance and Currency	conformity with scientific advances
10		current features and references
11	Motivational and Developmental Value	Develop a work ethic.
12		Encourage competition
13		Encourage curiosity
14		Provides a challenge to learn more
15	Pedagogical Effectiveness	Develop academic skills
16		Presenting material contextually

In addition to assessing student responses regarding content quality and pedagogical aspects of the application, we endeavoured to evaluate student perceptions of educational media evaluation. Table 8 presents the indicators and corresponding question instruments designed to measure these perceptions.

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Table 8. Educational Media Evaluation Instruments

No	Indicators	Question Item
1	Visual Design and Aesthetics	The media design is visually appealing
2		Colour selection used in media
3		The media is visually appealing and accessible
4	Content Relevance and Alignment	Media design based on Social Studies topics
5		Media packaging based on Social Studies topics
6		Incorporates concepts from the Social Studies
7		Videos relate to the material
8	Content Clarity and Organization	The script is readable and visible
9		Provided with a title/media description
10		The content presented in the media is coherently explained
11	Multimedia Integration	Design of media provides actual examples
12		Diverse media collection
13		The video sound used is clear
14		Audio and video are coherent
15	Pedagogical Effectiveness	Media develops interest in learning
16		Media encourages student engagement

The response instruments were administered to students during the third instructional meeting. Following the completion of the post-test learning assessment, students provided their feedback regarding the implementation of the TNBTS V-Lab application in Social Studies education. In addition to essay question instruments, this research utilizes a mobile learning virtual laboratory that has been specifically designed for this purpose. Here is the application link provided by V-Lab Mobile Learning: https://drive.google.com/file/d/1UaPq-j1iPMSqRbVDbjXO8tT1Vw2Un4Aq/view?usp=sharing. A visual representation of the V-Lab Mobile Learning application's appearance is shown in the following figures 3.

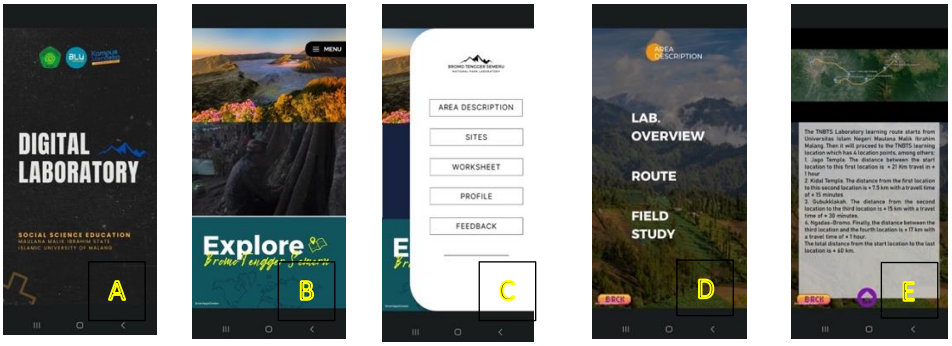

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Figure 3. A) Display of the Digital Laboratory Application, B) Front cover display, C) Main menu display, D) Description area menu display, E) Route menu display, F) Sites menu display, G) Display of one of the Sites, H) Worksheet view, I) Application developer profile view.

Based on the figures above, it is shown that the menu interface of the V-Lab Mobile Learning TNBTS program is well-organized and systematic, allowing access for users. The vibrant colour display, along with engaging videos, creates an appealing impression on users and prevents user boredom (Bashith et al., 2023). The validation and effectiveness testing of the V-Lab ML TNBTS application were conducted in this study, and the results demonstrated that the application is highly effective for the learning of social studies undergraduate students, with a score of 88.74% (Bashith et al., 2025).

3.5. Data Analysis

Data analysis employed parametric inferential statistics. This analysis was conducted to evaluate the effect of utilizing a field laboratory based on mobile learning to the learning outcomes of students in both the experimental and control groups. The statistical analysis employed the normality test, homogeneity test, and independent sample t-test using SPSS 22.0 for Windows, with a significance level of 0.05. The student t-test, which was designed to determine differences between two different sample groups with a small sample size, includes an independent sample t-test analysis (Campbell & Stanley, 1967). The decisions made are derived from hypothesis testing conducted on the data of learning outcome scores. The criteria are as follows: if sig. ≥ 0.05 then H0 is accepted and if Sig. < 0.05 then H0 is rejected.

4. Results

4.1. Learning Outcomes on the Topic of Economic Behavior of the Mount Tengger Slope Community

Data was obtained using a valid and reliable instrument (Table 5 and Table 6). Then, primary data was gathered by an initial evaluation in the form of a pre-test and another evaluation in the form of a post-test from students. The following figure 4 illustrated the learning outcomes of social sciences students before and after the pre-test and post-test, comparing the control group with the experimental group.

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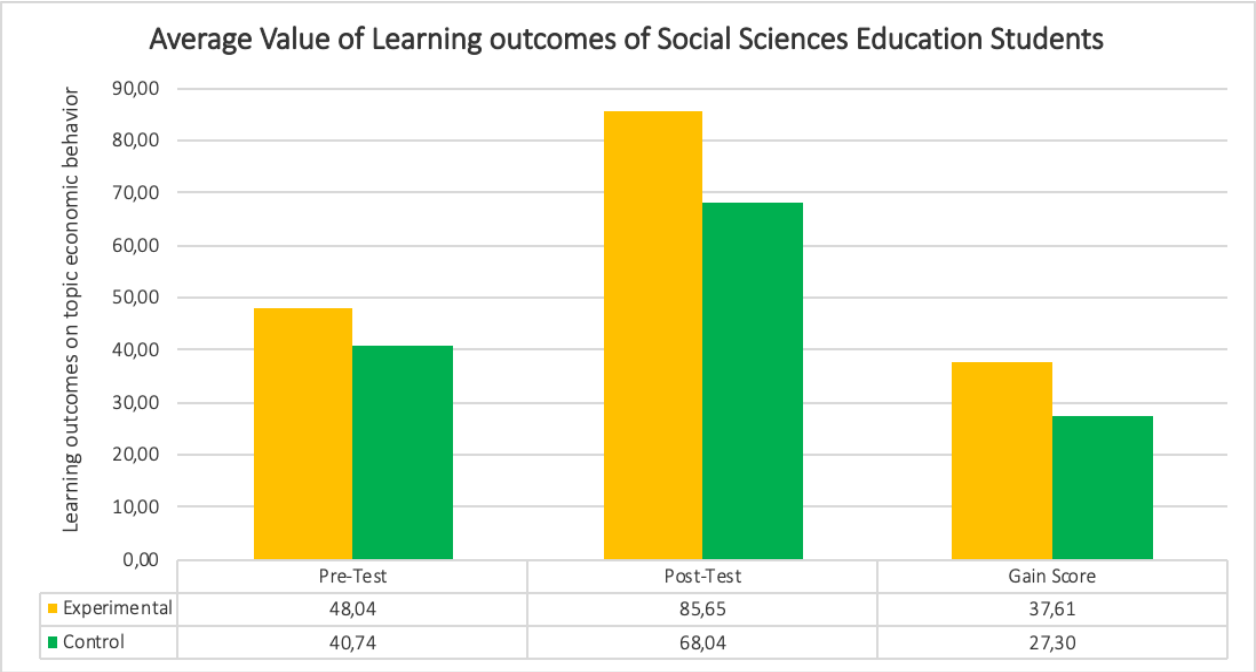

Figure 4. The Result of Learning outcomes of Social Sciences Education

According to Figure 4, the control group had a learning outcome of 40.74, whereas the experimental class achieved a learning outcome of 48.04 during the pre-test. The pre-test results for the control group were comparatively lower than those for the experimental group. The results obtained by the two groups in the pre-test indicated differences, though not significant as the results only differed by 7.3 points. After that, the post-test analysis revealed that the control group achieved a learning outcome of 68.04, whereas the experimental group attained a higher learning outcome of 85.65. It can be stated that during the post-test, the control group remained at a lower level compared to the experimental group. The experimental group achieved a gain score of 37.61 from the pre-test to the post-test, while the control group achieved a gain score of 27.30 during the same period. In general, there has been a significant improvement in learning outcomes for the experimental group when using the V-Lab ML TNBTS application, in comparison to the control group that used conventional teaching methods. Thus, there is a difference in the mean score of learning outcomes in the post-test between the two groups, it is required to do statistical analysis to determine the particular differences between the two groups. The next steps involve conducting normality testing, homogeneity testing, and an independent sample t-test on the learning outcomes.

4.2. Hypothesis Testing of Learning Outcomes

Furthermore, the importance of the learning outcomes was evaluated using the independent sample t-test. Prior to evaluating the differences in learning outcomes of the two research groups, normality and homogeneity tests are conducted. The following normality test results are shown in Table 9.

Table 9. Normality Test Results of Learning Outcomes

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Value	.084	47	.200*	.960	47	.104

The results of the normality test for the learning outcome scores of the experimental group are presented in Table 6. The significance value (sig.) obtained using the Kolmogorov-Smirnov approach is sig. = 0.200 < α = 0.05. Similarly, for the control class, the significance value obtained using the

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Shapiro-Wilk technique is sig. = 0.104 < α = 0.05. The significant results indicate that the data on learning outcomes for both the control and the experimental groups follow a normal distribution. To determine the hypothesis on learning outcomes, the independent sample t-test can be employed. After that, a homogeneity test was conducted to determine the variance in learning outcomes between the control group and the experimental group. The following findings relate to the homogeneity analysis of learning outcomes among students studying social sciences education (See Table 10).

Table 10. Homogeneity Test Results of Learning Outcomes

	Levene Statistic	df1	df2	Sig.
Based on Mean	.665	1	45	.419
Based on Median	.519	1	45	.475
Based on Median and with adjusted df	.519	1	44.948	.475
Based on trimmed mean	.685	1	45	.412

Based on table 10, it can be seen that the Sig. > α = 0.05. This indicates that the learning outcomes of social sciences students are homogeneous. Furthermore, to ensure that the difference in learning outcomes between the two research groups has increased significantly, an independent sample t-test can be carried out (See Table 11).

Table 11. Independent Sample T-test Results of Learning Outcomes

	Levene's Test		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	MD	S. ED	95%	
								Lower	Upper
Equal variances assumed	.665	.419	2.664	45	.011	10.984	4.123	2.679	19.288
Equal variances not assumed			2.671	44.746	.011	10.984	4.113	2.699	19.268

Table 8 data indicates that the significance level (2-tailed) is 0.011 < α 0.05. This demonstrates a significant increase in the learning outcomes for social sciences students from the pre-test to the post-test. The findings of this research confirm the hypothesis that was proposed before, specifically, hypothesis H0 is rejected and hypothesis H1 is accepted. The findings of this independent sample t-test demonstrate significant differences in learning outcomes between the control group and the experimental group that utilized the V-Lab ML TNBTS application. Therefore, it can be concluded that the utilization of V-Lab ML TNBTS highly enhances the learning outcomes of Social Sciences students in regards to the subject of Economic Behaviour of the Mount Tengger Slope Community.

5. Discussion

5.1. Learning Outcomes after using the TNBTS V-Lab application

Research findings indicate that the utilization of V-Lab ML TNBTS impacts students' learning outcomes by providing them with exposure to authentic environmental issues. The development of students' critical and analytical thinking skills about everyday life contexts occurs as they overcome these natural challenges (Kurniawan et al., 2022; Nicol et al., 2022). Students are motivated to show concern for environmental issues through the utilization of digital field laboratories (Nicol et al., 2022;

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Wijayanto et al., 2023). Direct field observation is necessary to investigate the issues using the digital field laboratory and attempt to find solutions in social environment. Implementing this approach can enhance the learning outcomes of students and their practical skills in problem-solving (Baladoh et al., 2017; Prahani et al., 2022). Students acquire a comprehensive and concrete comprehension of the problem, facilitating the collection of data and information for the purpose of identifying and selecting solutions (Al-nakhle, 2022; Saputra & Kuswanto, 2019).

This substantial difference in learning outcomes can be attributed to several key factors: Contextualization of Abstract Concepts: The virtual laboratory likely bridges the gap between theoretical concepts and practical applications, addressing a fundamental challenge in social sciences education. This aligns with Prasetya et al. (2024) and Prastiyono et al. (2021) findings on visualization benefits for complex social phenomena. Enhanced Engagement: The interactive nature of virtual laboratories typically increases student motivation and participation. Amin et al. (2022) found students using virtual laboratories showed 27% higher task persistence than those in traditional settings. Self-Paced Learning: Mobile-based virtual learning enables individualized progress, allowing deeper processing of complex material (Achuthan, 2018; Fatmaryanti et al., 2022).

The gain score differential (37.8%) exceeds improvements reported in comparable studies. Amin et al. (2022) observed only a 29% improvement when using virtual simulation tools for social studies in Indonesian university settings, while Bashith et al. (2022) reported a 31% improvement with mobile learning applications in undergraduate social sciences. The findings support both Kolb's Experiential Learning Theory and Cognitive Load Theory, suggesting the application facilitates experiential learning while reducing extraneous cognitive load through structured representations of complex concepts (Dlouhá & Pospíšilová, 2018; Sterling & Rieckmann, 2016; Vare et al., 2019). These results strongly support integrating virtual laboratory experiences into social sciences curricula, particularly for abstract concepts, and suggest blended learning approaches may optimize outcomes. Future research should address potential novelty effects, implementation quality variables, and specific content areas that most benefit from virtual laboratory approaches.

When utilizing V-Lab ML TNBTS, students engage in investigations and attempt to discover resolutions to the challenges encountered during the learning process within the V-Lab ML TNBTS application. The application eliminates the necessity for students to conduct direct observations in the field in order to acquire an in-depth understanding of the encountered issues (Gonzalez-Romo et al., 2023; Kapici et al., 2019). However, students have the opportunity to regularly investigate V-Lab ML TNBTS in order to get a more concrete and broad comprehension of the challenges they encounter (Hurtado-Bermúdez & Romero-Abrio, 2023; Shou, 2022). Therefore, this facilitates the procedure of gathering data and information required for the identification and selection of the optimal solution (Al-nakhle, 2022; Saputra & Kuswanto, 2019). Therefore, V-Lab ML TNBTS serves as both a platform for education and a valuable tool for improving students' abilities to address actual challenges in the environment (Amin et al., 2020; Prastiyono et al., 2021, 2023). This application enhances both academic performance and the acquisition of practical problem-solving abilities in students (Kravchenko et al., 2024; Manyilizu, 2023; Prahani et al., 2022; Tejado et al., 2021). The figure 5 demonstrates students engaging in various activities and experiencing a high level of comfort while utilizing V-Lab ML TNBTS for their learning process.

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Figure 5. A) Students discuss with the lecturer, B) Students discuss about V-Lab ML TNBTS, C) Students use V-Lab ML TNBTS, D) Students look comfortable and smile while studying.

Research has demonstrated that utilizing the V-lab ML TNBTS application has positive impacts on learning outcomes among students studying social science education, particularly in relation to the subject of Economic Behaviour of the Mount Tengger Slope Community. Moreover, utilizing this application further teaches awareness of actual environmental issues in their surroundings. This application facilitates the development of critical and analytical thinking skills in students, specifically in the context of daily activities. This program has the capability to enhance student motivation towards environmental issues and enhance their practical problem-solving skills (Caniglia et al., 2018). While this application enables students to get a thorough understanding without participating in direct field observations, it still allows students the chance to conduct actual investigation in the field. The application enables students to collect the required information and data for identifying problems and solution finding. After that, students actively participated in group discussions to discuss about the proposed solutions. In general, this application also facilitates students in enhancing their academic proficiency and practical expertise in addressing environmental issues in their surroundings.

Student engagement in classroom increase while utilizing the V-lab ML TNBTS application, as shown in Figure 1 and 2. Grouped learning enhances students' acquisition of new skills, namely communication skills for problem-solving and emotional and social learning (Kurowsky, 2023; Nicol et al., 2022; Prahani et al., 2022). Lecturers should prioritize the consideration of emotional states, social attributes, and reflective capacities (Aliman et al., 2024). Research findings have demonstrated that the utilization of virtual laboratories can enhance motivation, engagement, and learning outcomes among students (Amankwaa et al., 2023; Carroll et al., 2010; Oyelere et al., 2018).

5.2. Student response to the use of the TNBTS V-Lab application

In order to obtain comprehensive feedback from students regarding their learning experience using the V-Lab ML TNBTS application, the researcher asked questions to the students following their use of the program. Students provide quantitative answers to questions using a rating scale from 1 to 5: (1: not relevant/not good), (2: not relevant/not good), (3: quite relevant/fairly good), (4: relevant/good), (5: very relevant/very good). The responses provided by students are later examined to get the average answer for each question. For more details, see the following figure 6. This response addresses the preferences experienced by students following their use of the TNBTS V-Lab ML application.

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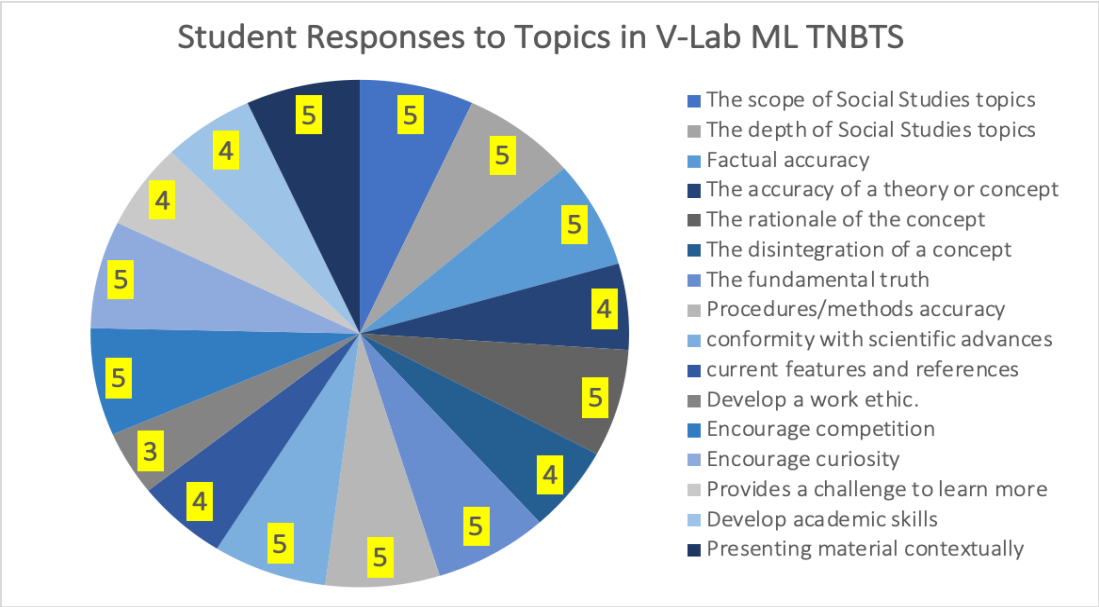

Figure 6. Student Responses to Topics in V-Lab ML TNBTS

Figure 6 demonstrates that the students' responses to the material content in the V-Lab ML TNBTS application were very favourable. Overall, the average rating for this response was 4.56, indicating that students responded very well to the utilization of V-Lab ML TNBTS. However, there is only one question that has a fairly good answer, which is the development of work ethic. This application requires additional improvements to enhance student work ethic. In order to fully prepare students for future employment, it is crucial to ensure that they possess a strong work ethic (Amankwaa et al., 2023). A graduate with strong work ethics can contribute significantly to his company (Senthilselvi et al., 2020). Therefore, it is important for the developer to enhance the functionality of this application, particularly to respond to student feedback. This application is expected to provide an engaging educational experience for students to gain knowledge about the Economic Behaviour of the TNBTS slope community. The findings of this study align with previous research suggesting that digital media in the form of virtual laboratories can enhance understanding and learning interest (Prasetya et al., 2024).

Meanwhile, the responses of students to the performance display and features included in the V-Lab ML TNTS program are shown in the following graph (See Figure 7).

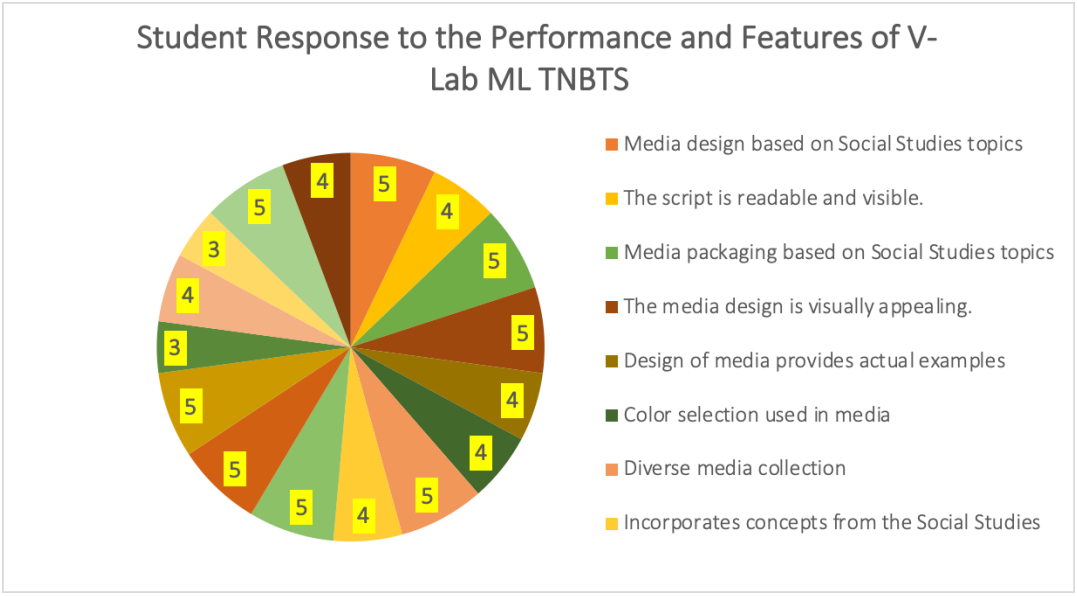

Figure 7. Student Response to the Performance and Features of V-Lab ML TNBTS

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The figure 7 indicates that the student response to the V-Lab ML TNBTS application is highly positive. This is demonstrated by one question that had a better answer. In addition to that, the answers were generally acceptable to excellent, with an average score of 4.37. The students are satisfied with the design and functionalities of the application. Students will find it easy to use using this application. However, this tool requires improvement in its ability to choose additional videos that enhance students' comprehension of the subject. The use of auditory and visual stimulating presentations has proven to enhance students' engagement and participation in the learning process (Kurniawan et al., 2022). The V-Lab ML TNBTS program has included both auditory and visual components. However, in the future, it is essential that the videos displayed show a consistent and integrated relationship among all the current sub-topics as a whole.

The implementation of sustainable social science education through V-Lab ML TNBTS experiences has transformed traditional learning approaches by promoting student autonomy and personalized learning paths (Prastiyono et al., 2023). Research demonstrates that accommodating diverse learning styles in virtual environments enhances student engagement and understanding of complex social-environmental issues (Lozano et al., 2019; Saputra & Kuswanto, 2019). For instance, multimedia elements such as background music and voice annotations have been shown to stimulate learning motivation among auditory learners (Nicolaou et al., 2019), while authentic field videos benefit visual learners in understanding community-based sustainability challenges. However, addressing the needs of kinaesthetic learners remains a challenge in virtual environments (Bashith et al., 2023). Studies suggest that facilitating various learning opportunities enhances student research enthusiasm and competency development (Brundiers et al., 2021; Haleem et al., 2022). The correlation between enjoyable learning experiences and positive learning outcomes has been well-documented (Ali et al., 2023; Manyilizu, 2023). To accommodate kinaesthetic learners, direct community engagement through field observations is recommended (Caniglia et al., 2018), allowing students to develop practical understanding of social issues and propose effective solutions. This approach aligns with the principles of place-based education and experiential learning in sustainable social science education (Sterling & Rieckmann, 2016), fostering deeper understanding of community challenges and promoting sustainable development initiatives.

Active learning has emerged as a crucial component in sustainable social science education, enabling students to deeply engage with subject matter while developing critical skills and expanding their knowledge base (Aliman et al., 2024; Fang et al., 2023). Digital field laboratories have demonstrated significant positive impacts on student learning outcomes, particularly in understanding complex socio-economic behaviours of communities (Bashith et al., 2025). The research by aligns with recent findings in sustainable education practices, showing that digital field laboratories enhance both learning outcomes and developmental processes. This approach enables students to conduct comprehensive internet research, accessing data and information sources beyond traditional field limitations, thereby fostering learning independence and digital literacy (Lozano et al., 2019). Studies consistently demonstrate that virtual laboratories improve knowledge acquisition, confidence building, and learning autonomy (Amankwaa et al., 2023; Carroll et al., 2010; Kravchenko et al., 2024), which are essential components of sustainable social science education. The enhancement of students' knowledge through these platforms directly contributes to their problem-solving capabilities (Haleem et al., 2022; Manyilizu, 2023; Prahani et al., 2022), reflecting the core principles of solution-oriented sustainability learning (Brundiers et al., 2021). Digital field laboratories in social studies have demonstrated multifaceted benefits, improving both learning outcomes and technological literacy (Erdoğan & Bozkurt, 2022; Tuysuz, 2010). This integration of technology in social science education prepares students with essential 21st-century skills (Amin et al., 2022; Prastiyono et al., 2021), while simultaneously addressing the need for transformative approaches in sustainability education (Sterling & Rieckmann, 2016). The combination of digital tools

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and sustainable social science education creates a robust framework for developing competent, technologically-savvy professionals capable of addressing complex societal challenges.

V-Lab ML TNBTS has transformed sustainable social science education by integrating digital learning with real-world environmental challenges (Baron et al., 2024; Lozano et al., 2019). The platform strengthens students' critical thinking through interactive environmental problem-solving experiences (Kurniawan et al., 2022; Nicol et al., 2022), while its multimedia approach effectively enhances student motivation and comprehension (Nicolaou et al., 2019). Although the platform promotes digital literacy and independent learning (Amankwaa et al., 2023; Kravchenko et al., 2024), it recognizes the importance of field experiences for hands-on learners (Caniglia et al., 2018). Student satisfaction ratings of 4.56/5 demonstrate the platform's effectiveness, despite needed improvements in work ethic development (Senthilselvi et al., 2020). Technology successfully combines with sustainability education (Prahani et al., 2022; Sterling & Rieckmann, 2016), V-Lab ML TNBTS creates an environment that develops both academic and practical problem-solving skills (Bashith et al., 2025; Brundiers et al., 2021). Future enhancements should focus on video content integration and work ethic development to maintain its educational impact in sustainable social science education.

5.3. Conceptual Model of Virtual Laboratory Development Based on Mobile Learning for Social Science Education Students

Based from the research findings and preceding discussion, we have developed a conceptual framework for virtual reality application implementation in social studies education. This framework offers transferability to related academic disciplines and diverse subject matter, as illustrated in Figure 8.

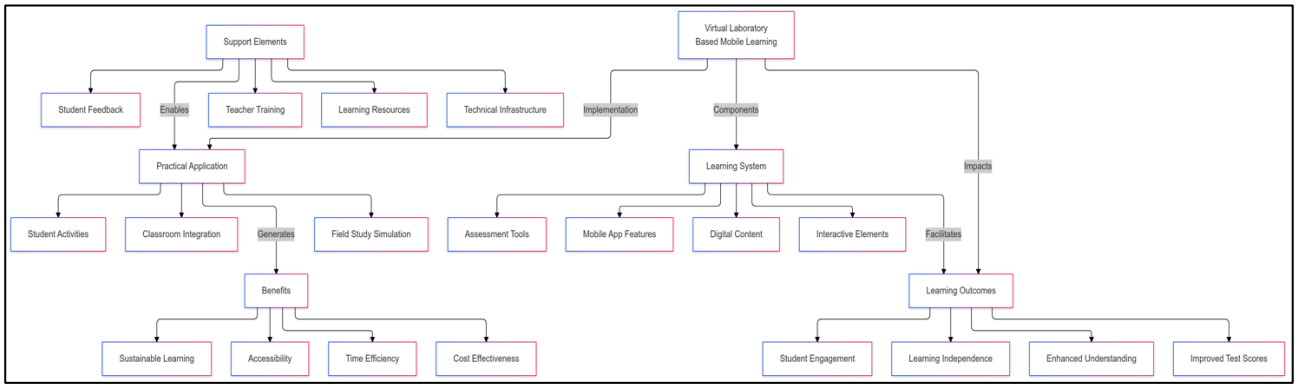

Figure 8. Conceptual Model of Mobile Learning-Based Virtual Laboratory for Social Science Education Students

The conceptual model above illustrates an integrated educational innovation system that combines digital technology with pedagogical approaches to enhance learning outcomes. The system comprises four interconnected fundamental components facilitating effective education delivery: Learning System, Learning Outcomes, Practical Applications, and Supporting Elements.

The Learning System incorporates mobile application features, digital content, interactive elements, and assessment tools that collectively create an engaging virtual learning environment. This foundation directly influences Learning Outcomes, manifested in improved comprehension, enhanced test scores, increased student engagement, and greater learning autonomy. This integrated approach ensures that mobile-based virtual laboratory learning not only enhances educational delivery but also promotes sustainable and accessible learning experiences for Social Science Education students (Bashith et al., 2023).

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The learning model's strength lies in its holistic approach, acknowledging both technical and pedagogical aspects of virtual learning while emphasizing support systems and practical benefits. It demonstrates how mobile learning can effectively simulate laboratory experiences, particularly valuable in social science education where field observations and practical applications are crucial for student understanding. This conceptual model serves as both a comprehensive framework and implementation guide for educational institutions aiming to integrate similar systems into the Social Science Education study program, showcasing how technology can create enriched learning experiences while maintaining educational efficiency and effectiveness.

6. Conclusion

Based on the discussion, it can be concluded that the V-Lab ML TNBTS application is effective for social science students. Furthermore, the use of this application has successfully enhanced student learning outcomes about the Economic Behaviour of the Mount Tengger Slope Community. This research significantly improves the knowledge of social science education students in utilizing V-Lab ML TNBTS. The findings of this study contribute to the integration of education in the digital era, resulting from advancements in information technology. Based on the findings of this study, it is recommended that future developments should improve the work ethic features and video content integration in the V-Lab TNBTS application, combine virtual experiences with field observations, expand the conceptual model to other social science disciplines, and provide educator training for effective implementation.

The V-Lab ML TNBTS application needs to be further developed in a wider scope and popular commercial application domains because it is still being tested in learning and application domains with a limited scope. Two potential areas for future research include: 1) performing experiments with students from different departments utilizing the V-Lab ML TNBTS application, focusing on relevant material for the application, and 2) conducting trials with the V-Lab ML TNBTS application, exploring its impact on other cognitive characteristics. The research suggests that researchers could enhance the V-Lab ML TNBTS application to improve its effectiveness and flexibility for classroom learning by lecturers or teachers.

7. Suggestion

The implication of this study's findings pertains to the importance of developing and evaluating the V-Lab ML TNBTS application to a variety of subjects and learning environments in different areas. Experimental evaluation involving several departments are necessary. Further research is required to investigate the impact of the V-Lab ML TNBTS application on various cognitive characteristics. It is needed for encouragement and support from Educational Institutions to implement this application. It is also needed for collaboration and financial assistance to advance and implement this application in other educational institutions.

Declarations

Author Contributions. A.B: Conceptualization, writing, data collection and writing research proposal. S.A: Writing, data collection. M.A: Data analysis, Writing. M.A.K: Data collection, Data validation, Language editing. H.J: Language editing, Data validation. L.M: Data processing and analysis. All authors agree to all published articles.

Conflicts of Interest. Authors declare that there is no conflict of interest within this research, publication paper, and funding support.

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Data Availability Statement. The primary data contained in this study can be obtained upon request to the corresponding author.
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About the Contributor(s)

Abdul Bashith, is a doctor, lecturer, and researcher at Department of Social Science Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Maulana Malik Ibrahim Malang, Indonesia. Expertise: Social Studies Education, Economic Education, Economic Empowerment of Islamic Boarding School Communities, Learning Technology. Latest Research: Implementation of the Integrated Living Laboratory Learning Model in Social Studies Education. Email: abbash98@pips.uin-malang.ac.id.
ORCID: https://orcid.org/0000-0003-4678-3891

Saiful Amin, is a doctor, lecturer, and researcher at Department of Social Science Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Maulana Malik Ibrahim Malang, Indonesia. He has successfully completed his bachelor degree, master of education degree, and PhD in Geography Education from Universitas Negeri Malang, Indonesia. Field of expertise's in geography learning, education & teacher training, social science education, and social sensitivity.
Email: amin.geo87@pips.uin-malang.ac.id
ORCID: https://orcid.org/0000-0001-5408-2898

Muhammad Aliman, is a doctor in Geography Education, a research assistant in the geography department, Universitas Negeri Malang. Expert in geography learning, local wisdom, environmental education. The latest research is related to students' spatial learning in schools.
Email: alviageo@gmail.com
ORCID: https://orcid.org/0000-0001-9918-3991

Muchammad Akbar Kurniawan, is student collage at Department of Social Science Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Maulana Malik Ibrahim Malang, Indonesia. Expertise: Social Studies Education, Learning Technology. Latest Research: Increasing Student Learning Activities in Social Studies through the Syndicate Group Method.
Email: 210102110072@student.uin-malang.ac.id
ORCID: https://orcid.org/0009-0003-7402-0426

Hasse Jubba is an associate professor at Universitas Muhammadiyah Yogyakarta. Expertise: Religious Studies/ Sociology of Religion. Latest research: Survival Strategy of Muslim Minority Groups in Indonesia.
Email: hasse@umy.ac.id
ORCID: https://orcid.org/0000-0002-4171-2501

Linda Maulidiah, have successfully completed a Master degree at the School of Geographical Sciences, Nanjing Normal University, PR China. Expertise: Urban Geography, Smart Cities, Demographics, Population Growth. Recent Research: The Concept of Eco-Cities in Indonesia and China with Carbon Neutrality and Climate Change Perspective: Literature Review.
Email: 31212003@njnu.edu.cn
ORCID: https://orcid.org/0009-0005-2630-3821