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Guided Inquiry Strategies Through Virtual Laboratories in Students' Learning and Performance in Environmental Science

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Abstract— *This study examined the role of guided inquiry strategies in virtual laboratories and their influence on students' learning and performance in environmental science education. It investigated the level of students' virtual laboratory usage, learning outcomes and their performance as to written and performance output. In addition, to find out the relationship between students' use of guided inquiry strategy through virtual laboratory and their learning outcomes and its effect to their performance. Employing a descriptive approach, this study was conducted during the second semester of the 2023–2024 academic year at Laguna University, the study involved 150 environmental science students. Statistical analysis was performed using descriptive statistics and Pearson correlation analysis. The findings revealed that the guided inquiry strategy through virtual laboratories, learning outcomes were perceived at a high level. The performance of the students was very satisfactory in both written test and performance tasks. While no significant relationship was found between guided inquiry strategies and overall learning outcomes, the strategies had a notable effect on students' written and performance tasks. In line with the findings this study, it established that no significant relationship was found between guided inquiry strategies through virtual laboratories and overall learning outcomes of the students. Thus, the posited null hypothesis is accepted. Moreover, the study reveals a significant effect of using guided inquiry strategies through virtual laboratories on students' performance. Thus, the posited null hypothesis is rejected.. Based on these findings, the study recommends providing teachers with training and modules on guided inquiry, integrating active learning strategies in virtual laboratories, and expanding access in resource-limited settings. It also suggests collecting regular feedback for improvement and encourages future researchers to explore moderating factors like prior knowledge and learning styles to optimize learning outcomes.*

Keywords— *Guided Inquiry, Virtual Lab, Performance, Simulation, Learning.*

I. INTRODUCTION

The need for innovative teaching strategies in environmental science education has grown significantly in recent years. As environmental issues become more complex, students must develop critical thinking, problem-solving, and analytical skills to address real-world challenges effectively. To support this, educators are exploring various instructional strategies that enhance student engagement and learning outcomes.

One such strategy is the guided inquiry strategy, which fosters a discovery-oriented learning experience where students take on the role of scientists. This inquiry-based learning strategy encourages students to pose their questions and actively engage in problem-solving, enhancing their ability to think critically and scientifically. The process incorporates essential scientific practices such as measurement, classification, observation, inference, and communication of results.

In line with this, research shows that guided inquiry can significantly enhance students' learning outcomes. In guided inquiry learning, students explore various knowledge sources to deepen their understanding of scientific concepts, fostering curiosity and real-world connections rather than just providing correct answers. his approach encourages active engagement and independent thinking.

In modern classrooms, teachers primarily serve as facilitators, guiding students through the learning process while incorporating technology to enrich instruction. Multimedia tools enable students to revisit and review learning materials multiple times until they fully grasp the content. One essential technological tool in this framework is the virtual laboratory, which has revolutionized science education by providing students with interactive and immersive learning experiences. Researchers and educators increasingly advocate for the integration of technology into teaching due to its proven positive impact on student learning. A key area where technology has demonstrated substantial benefits is in virtual laboratory activities.

Moreover, virtual laboratories offer interactive platforms where students engage with simulations that illustrate both microscopic and macroscopic phenomena across various scales, making scientific concepts more tangible and accessible. According to Levytska (2024), virtual laboratories, designed as web applications with user-friendly interfaces, allow students to work at their own pace, repeat experiments, and tailor their learning approaches to suit their individual needs. This flexibility enhances students' understanding and retention of complex scientific concepts.

Despite the advantages of virtual laboratories, their integration with guided inquiry strategies remains relatively uncommon, particularly in the development of students' science process skills. Furthermore, the effectiveness of this instructional strategy in improving these skills requires further investigation through comprehensive data analysis. While there is growing interest in virtual laboratories, additional research is necessary to explore how these tools impact student engagement and understanding of environmental science, especially in addressing real-world environmental

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challenges. Therefore, this study aims to highlight the significance of utilizing guided inquiry strategies through virtual laboratories to enhance students' mastery of science process skills.

With this, the researcher aimed to determine the effectiveness of the guided inquiry strategy through a virtual laboratory in students' learning and performance in environmental science.

1.1 Statement of the Problem

Problem/s which were addressed by the research

This study focused on evaluating how virtual laboratories, when utilized with guided inquiry strategies, influence students' knowledge acquisition, skills development, engagement, and performance. It sought to explore more of the current research problem:

1. What is the level of using guided inquiry strategies through a virtual laboratory as to:
   1.1. Simulation;
   1.2. Interactivity Level;
   1.3. Interface Complexity;
   1.4. Collaborative; and
   1.5. Integration?
2. What is the level of students' learning outcome in terms of:
   2.1. Knowledge Acquisition;
   2.2. Skill Development; and
   2.3. Engagement?
3. What is the level of students' performance as to:
   3.1. Written Test; and
   3.2. Performance Task?
4. Is there a significant relationship between using guided inquiry strategies through virtual laboratory and students' learning outcomes?
5. Is there a significant effect in using guided inquiry strategies through virtual laboratory on students' performance?

II. Methodology

Employing a descriptive approach, this study was conducted during the second semester of the 2023–2024 academic year at Laguna University, the study involved 150 environmental science students. Statistical analysis was performed using descriptive statistics and Pearson correlation analysis.

III. Results and Discussion

This part presents the different results and discusses the results from treating the data gathered in this study. This chapter provided tables to back up the answers to all of the specific questions posed in Chapter 1 under the statement of the problem. It presents the data gathered about the significant relationship between using a virtual laboratory and students' learning outcomes. In particular, the study sought to address the following:

Level of Using Virtual Laboratory

In the context of this study, the level of virtual laboratory use is evaluated across five key dimensions: Simulation, Interactivity Level, Interface Complexity, Collaboration, and Integration. These components collectively reflect how effectively virtual laboratories are implemented and utilized in the learning process. To provide a thorough understanding of these aspects, the following tables present detailed results collected from the respondents.

The table 1 presents the respondents' perceptions of the use of virtual laboratories, focusing on five key dimensions: Simulation, Interactivity Level, Interface Complexity, Collaboration, and Integration. It includes the corresponding statements, mean scores, standard deviations, remarks, and verbal interpretations to reflect the overall level of virtual lab usage in the learning process. These dimensions were carefully selected to capture both the technical and pedagogical aspects of guided inquiry strategy through virtual laboratory use.

TABLE 1. Level of using guided inquiry strategies through virtual laboratory in terms of Simulation

	Mean	SD	Remarks
The simulations in the virtual laboratory accurately represent real-world scenarios.	4.05	0.85	Agree
The simulations provide a realistic experience that enhances my understanding of concepts.	4.13	0.79	Agree
I feel that the virtual simulations allow me to apply theoretical knowledge effectively.	4.07	0.79	Agree
The simulations are an effective substitute for traditional laboratory experiences.	4.01	0.86	Agree
The simulations in the virtual lab contribute to my learning in environmental science.	4.25	0.83	Strongly Agree
Weighted Mean	**4.10**		
SD	**0.82**		
Verbal Interpretation	**High**		

Table 1 shows the level of using virtual laboratories in terms of simulation. The computed weighted mean of 4.10 with a standard deviation of 0.82 indicates a high level of agreement among respondents regarding the effectiveness of simulations in enhancing learning.

This implies that virtual simulations provide realistic experiences that help students apply theoretical knowledge effectively. The high ratings also reveal that simulations serve as a valuable substitute for traditional laboratory experiences, reinforcing students' understanding of scientific concepts. Additionally, the ability to engage with real-world scenarios through simulations enhances students' problem-solving skills and overall learning experience.

These findings align with Kibirige (2024), who indicated that simulation positively impacts student motivation, engagement, and success. This supports the idea that well-designed virtual simulations contribute to a more interactive and immersive educational environment, improving knowledge retention and application.

Table 2 presents the level of using virtual laboratories in terms of interactivity. The computed weighted mean of 4.10 with a standard deviation of 0.80 indicates a high level of agreement among respondents regarding the interactive features of the virtual laboratory. This implies that the interactivity of the virtual lab enhances engagement,

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motivation, and comprehension of complex concepts. The ability to manipulate variables and control experiments fosters deeper learning by allowing students to explore scientific principles independently. Additionally, the interactive nature of the virtual lab encourages critical thinking and problem-solving, essential skills for academic and professional success.

TABLE 2. Level of using guided inquiry strategies through virtual laboratory in terms of Interactivity Level

	Mean	SD	Remarks
The virtual laboratory offers sufficient interactive features to keep me engaged.	4.10	0.76	Agree
I can control and manipulate variables within the virtual labs.	4.05	0.85	Agree
The interactive elements help me understand complex concepts better.	4.14	0.81	Agree
I find the level of interaction in the virtual lab motivating.	4.06	0.80	Agree
The interactivity of the virtual lab improves my understanding of environmental science.	4.17	0.78	Agree
Weighted Mean	**4.10**		
SD	**0.80**		
Verbal Interpretation	**High**		

These findings align with Nikishina (2022), who indicated that interactive learning fosters active student participation by allowing them to provide input and receive feedback. This suggests that virtual laboratories create a dynamic and immersive educational experience that strengthens conceptual understanding.

TABLE 3. Level of using guided inquiry strategies through virtual laboratory in terms of Interface Complexity

	Mean	SD	Remarks
I find the virtual lab interface intuitive and easy to navigate.	4.05	0.82	Agree
The complexity of the interface does not hinder my learning.	4.03	0.84	Agree
I am comfortable using the tools provided in the virtual laboratory.	4.01	0.87	Agree
The interface is user-friendly for completing tasks in the virtual lab.	4.11	0.84	Agree
The visual layout of the virtual lab interface is clear and accessible.	4.17	0.88	Agree
Weighted Mean	**4.05**		
SD	**0.85**		
Verbal Interpretation	**High**		

Table 3 presents the level of using virtual laboratories in terms of interface complexity. The weighted average of 4.05, with a standard deviation of 0.85, shows that respondents had a high degree of consensus about how simple it was to use and navigate the virtual laboratory interface. This implies that the interface is intuitive, user-friendly, and does not create significant challenges for students in completing tasks. The results further reveal that the tools and visual layout are accessible, allowing users to comfortably interact with the platform without experiencing unnecessary cognitive load.

These findings align with Thomas (2024), who emphasized that a well-designed interface reduces cognitive overload, enabling students to focus more on learning rather than usability issues. This reinforces the importance of intuitive digital platforms in optimizing the virtual learning experience and supporting effective engagement with laboratory simulations.

TABLE 4. Level of using guided inquiry strategies through virtual laboratory in terms of Collaborative

	Mean	SD	Remarks
The virtual lab provides opportunities for collaboration with classmates.	4.16	0.78	Agree
I feel encouraged to communicate with peers in the virtual lab setting.	4.12	0.81	Agree
The collaborative tools in the virtual lab are useful for group activities.	4.21	0.84	Strongly Agree
I enjoy collaborating with others in the virtual lab.	4.15	0.86	Agree
Collaborative tasks in the virtual lab enhance my understanding of environmental science.	4.27	0.77	Strongly Agree
Weighted Mean	**4.18**		
SD	**0.81**		
Verbal Interpretation	**High**		

Table 4 presents the level of using virtual laboratories in terms of collaboration. The computed weighted mean of 4.18 with a standard deviation of 0.81 indicates a high level of agreement among respondents regarding the collaborative features of the virtual lab. This implies that the platform effectively facilitates peer communication, teamwork, and group activities, enhancing students' engagement and interaction. Additionally, the results reveal that collaborative tasks contribute positively to their learning experience, particularly in environmental science.

These findings align with Hattie (2020), who highlighted that collaboration fosters knowledge-sharing and teamwork, ultimately improving learning outcomes. The integration of collaborative tools in virtual laboratories promotes active learning, encouraging students to engage in meaningful discussions and problem-solving activities.

TABLE 5. Level of using guided inquiry strategies through virtual laboratory in terms of Integration

	Mean	SD	Remarks
The virtual lab activities are well-integrated with the course objectives.	4.09	0.84	Agree
I find that the virtual lab aligns with what I learned in lectures.	4.09	0.74	Agree
The virtual lab tasks enhance my understanding of environmental science topics.	4.09	0.77	Agree
The virtual labs are effectively incorporated into the overall curriculum.	3.96	0.78	Agree
Virtual lab experiences support my understanding of environmental science concepts.	4.16	0.83	Agree
Weighted Mean	**4.08**		
SD	**0.79**		
Verbal Interpretation	**High**		

Table 5 presents the level of using virtual laboratories in terms of integration. The computed weighted mean of 4.08 with a standard deviation of 0.79 indicates a high level of agreement among respondents regarding the seamless alignment of virtual lab activities with course objectives and curriculum. This implies that the virtual laboratory effectively reinforces lecture content, enhances understanding of environmental science topics, and supports overall learning. Furthermore, the results reveal that the integration of virtual

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lab experiences contributes to a more structured and comprehensive learning process.

These findings align with Berry (2024), who emphasized that well-integrated digital learning tools create meaningful connections between theoretical concepts and practical applications. By incorporating virtual labs into the curriculum, students gain a more cohesive learning experience that strengthens their comprehension and retention of subject matter.

TABLE 6. Composite table on the level of using guided inquiry strategies through virtual laboratory

Indicators	Weighted Mean	SD	Verbal Interpretation
Simulation	4.10	0.82	High
Interactivity Level	4.10	0.80	High
Interface Complexity	4.05	0.85	High
Collaborative	4.18	0.81	High
Integration	4.00	0.79	High
Grand Mean	**4.09**		
SD	**0.81**		
Verbal Interpretation	**High**		

The level of using virtual laboratories in terms of Simulation, Interactivity Level, Interface Complexity, Collaborative, and Integration arrived at a grand mean score of 4.09 with a standard deviation of 0.81, which was verbally interpreted as high among the respondents. This indicates that virtual laboratories are widely accepted as effective learning tools, providing realistic simulations, interactive features, user-friendly interfaces, collaborative opportunities, and well-integrated course content.

These findings imply that virtual laboratories enhance student engagement, facilitate hands-on learning experiences, and support knowledge retention across various academic disciplines. The high level of utilization suggests that integrating virtual labs into the curriculum fosters active learning, critical thinking, and collaboration among students. Moreover, the effectiveness of virtual labs in providing accessible, flexible, and immersive learning environments aligns with Wennett (2023), who highlighted the importance of integrating multiple instructional strategies to promote deeper conceptual understanding.

Level of students' learning outcome

In this study, the level of students' learning outcome refers to Knowledge Acquisition, Skill Development**,** and Engagement. The following tables show the statement, mean, and standard deviation. remarks and verbal interpretation from the perspectives of respondents.

Table 7 presents the level of students' learning outcomes in terms of knowledge acquisition. The computed weighted mean of 4.17 with a standard deviation of 0.83 indicates a high level of agreement among respondents regarding the effectiveness of virtual laboratories in enhancing their understanding of environmental science. This implies that virtual labs serve as valuable educational tools, making complex scientific concepts more accessible and improving students' ability to retain information. Furthermore, the results reveal that virtual lab experiences contribute to strengthening students' theoretical knowledge and facilitating deeper learning.

TABLE 7. Level of students' learning outcome in terms of Knowledge Acquisition

	Mean	SD	Remarks
I feel that the virtual lab sessions have improved my knowledge of environmental science.	4.23	0.77	Strongly Agree
I have learned new concepts effectively through virtual labs.	4.19	0.78	Agree
The virtual labs make complex scientific concepts easier to understand.	4.17	0.82	Agree
I can retain information better after using the virtual labs.	4.15	0.85	Agree
The virtual labs have increased my theoretical understanding of environmental science.	4.09	0.94	Agree
Weighted Mean	**4.17**		
SD	**0.83**		
Verbal Interpretation	**High**		

These findings align with Ersoy (2022), who emphasized that simulations are widely used in higher education to promote inquiry, problem-solving, and conceptual understanding. Similarly, Hamstra (2021) highlighted that interactive learning tools, such as virtual labs, enhance students' critical thinking and comprehension by providing hands-on, immersive experiences. By integrating virtual labs into academic instruction, students are better equipped to grasp and retain new concepts, ultimately improving their overall learning outcomes.

TABLE 8. Level of students' learning outcome in terms of Skill Development

My School Head…	Mean	SD	Remarks
The virtual labs have helped me develop my practical skills.	4.12	0.76	Agree
I can apply the skills learned in the virtual labs to real-life scenarios.	3.99	0.86	Agree
My analytical skills have improved through virtual lab exercises.	4.14	0.78	Agree
Virtual labs help me practice problem-solving in environmental science.	4.09	0.78	Agree
I feel more confident in my skills after completing virtual lab sessions.	4.10	0.89	Agree
Weighted Mean	**4.09**		
SD	**0.81**		
Verbal Interpretation	**High**		

Table 8 presents the level of students' learning outcomes in terms of skill development. The computed weighted mean of 4.09 with a standard deviation of 0.81 indicates a high level of agreement among respondents regarding the effectiveness of virtual laboratories in enhancing their practical and analytical skills. This implies that virtual lab experiences contribute to the development of problem-solving abilities and the application of learned skills in real-life scenarios. Furthermore, the results reveal that virtual labs help students build confidence in their skills through hands-on exercises and interactive problem-solving activities.

These findings align with Moreno (2020), who emphasized that simulation-based learning provides practice-oriented education that helps students develop technical and analytical competencies. Likewise, Ozogul (2020) highlighted that

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interactive digital tools enhance students' ability to analyze, evaluate, and apply scientific knowledge in practical settings. By engaging in virtual lab activities, students gain essential problem-solving and critical-thinking skills that prepare them for real-world applications.

TABLE 9. Level of students' learning outcome in terms of Engagement

	Mean	SD	Remarks
I find virtual labs engaging and motivating.	4.17	0.85	Agree
The virtual labs keep my attention throughout the activities.	4.08	0.77	Agree
I am actively involved when using the virtual labs.	4.01	0.80	Agree
I feel more connected to the subject matter through virtual labs.	4.00	0.78	Agree
Virtual labs increase my interest in environmental science.	4.10	0.82	Agree
Weighted Mean	**4.07**		
SD	**0.80**		
Verbal Interpretation	**High**		

Table 9 presents the level of students' learning outcomes in terms of engagement. The computed weighted mean of 4.07 with a standard deviation of 0.80 indicates a high level of agreement among respondents regarding the ability of virtual laboratories to sustain student engagement and motivation. This implies that virtual labs effectively capture students' interest, maintain their attention, and foster active participation in learning activities. Furthermore, the results reveal that virtual labs enhance students' connection to the subject matter, making the learning experience more immersive and stimulating.

These findings align with Stupina (2024), who emphasized that interactive learning fosters engagement by positioning students as active participants rather than passive recipients of information. By incorporating virtual labs into instruction, educators can provide students with a dynamic and interactive learning environment that encourages curiosity and sustained academic engagement.

TABLE 10. Composite table on the level of students' learning outcome

Indicators	Weighted Mean	SD	Verbal Interpretation
Knowledge Acquisition	4.17	0.83	High
Skill Development	4.09	0.81	High
Engagement	4.07	0.80	High
Grand Mean	**4.11**		
SD	**0.81**		
Verbal Interpretation	**High**		

The level of students' learning outcomes in terms of Knowledge Acquisition, Skill Development, and Engagement arrived at a grand mean score of 4.11 with a standard deviation of 0.81, which was verbally interpreted as high among the respondents. This indicates that students perceive virtual laboratories as effective in enhancing their knowledge, refining their skills, and sustaining their engagement in learning activities. The results imply that virtual labs provide a comprehensive and interactive learning experience, allowing students to grasp complex concepts, develop practical competencies, and stay motivated throughout the learning process.

These findings align with Hamstra (2021), who emphasized that simulation-based learning significantly improves students' ability to acquire and retain knowledge while fostering critical thinking and problem-solving skills. Additionally, Lopez (2020) highlighted the importance of collaborative and engaging learning environments in enhancing students' motivation and overall academic performance. By integrating virtual labs into the curriculum, educators can create an enriched learning experience that supports both conceptual understanding and hands-on application, ultimately contributing to higher student achievement and deeper engagement in the subject matter.

TABLE 11. Level of students' Performance as to Written Test

Score	f	%	Descriptive Equivalent
57 - 70	36	24.00	Outstanding
43 – 56	70	46.67	Very Satisfactory
29 – 42	43	28.67	Satisfactory
15 – 28	1	0.67	Fairly Satisfactory
0 - 14	0	0.00	Did not meet Expectation
Total	**150**	**100**	
Weighted Mean		48.22	
SD		9.81	
Verbal Interpretation		Very Satisfactory	

Table 11 presents the level of students' performance in the Written Test based on their test scores. The computed weighted mean increased from 44.69 to 48.22, with standard deviations of 9.76 and 9.81, respectively. The test results were verbally interpreted as Very Satisfactory, indicating an overall improvement in students' written test performance after engaging with virtual laboratory activities.

The results imply that the use of virtual laboratories contributed to enhancing students' conceptual understanding and problem-solving skills, leading to higher test scores. The increase in the number of students achieving Outstanding and Very Satisfactory ratings suggests that interactive digital tools effectively reinforce learning, making abstract concepts more accessible.

These findings align with Ozogul (2020), who emphasized that simulation-based models enhance students' ability to analyze, evaluate, and generalize learning experiences by mimicking real-world scenarios. This supports the idea that virtual laboratories provide meaningful and structured learning opportunities that improve academic performance.

TABLE 12. Level of students' Performance as to Performance Task

Score	f	%	Descriptive Equivalent
20 - 24	73	48.67	Outstanding
15 - 19	77	51.33	Very Satisfactory
10 - 14	0	0.00	Satisfactory
5 - 9	0	0.00	Fairly Satisfactory
0 - 4	0	0.00	Did not meet Expectation
Total	**150**	**100**	
Weighted Mean	19.20		
SD	2.11		
Verbal Interpretation	Very Satisfactory		

Table 12 presents the level of students' performance in the Performance Task based on rubrics. The computed weighted mean of 19.20 with a standard deviation of 2.11 was verbally interpreted as Very Satisfactory, indicating that most students

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exhibited strong performance in laboratory-related tasks. A significant portion of the respondents (51.33%) achieved a Very Satisfactory rating, while 48.67% reached the Outstanding level, demonstrating a high level of competency in applying practical skills.

The results show that virtual laboratory activities effectively enhanced students' practical skills and engagement. All students performed within the higher rubric categories—Excellent or Good—across the six criteria: Building Design, Material Selection, Energy Efficiency, Solar Panel Use, Climate and Location Settings, and Innovation and Creativity. The absence of lower scores (Needs Improvement or Incomplete) indicates strong adaptation to performance-based tasks, allowing students to apply sustainable design principles and problem-solving skills effectively.

These findings align with Lopez (2020), who emphasized that interactive and collaborative digital learning environments help learners develop essential skills by allowing them to apply theoretical knowledge in real-world scenarios. This reinforces the effectiveness of virtual laboratories in bridging the gap between conceptual learning and practical application, ultimately improving student performance.

Test of Relationship between using guided inquiry strategies through virtual laboratory and the students' learning outcome

To test the significant relationship between the virtual laboratory and the students' learning outcome in terms of Knowledge Acquisition, Skill Development, and Engagement they were treated statistically using Real Statistics Data Analysis Tools using the Pearson product moment correlation coefficient.

TABLE 13. Significant Relationship between using guided inquiry strategies through virtual laboratory and the students' learning outcome

Virtual laboratory		Students' learning outcome		
		Knowledge Acquisition	Skill Development	Engagement
Simulation	Pearson Correlation	0.316	0.4073	0.5084
	Significance (2-Tailed)	0.3444	0.8178	0.6108
	N	149	149	149
	Analysis	Not Sig	Not Sig	Not Sig
Interactivity Level	Pearson Correlation	0.5343	0.4998	0.5397
	Significance (2-Tailed)	0.2727	0.7623	0.5581
	N	149	149	149
	Analysis	Not Sig	Not Sig	Not Sig
Interface Complexity	Pearson Correlation	0.3870	0.4167	0.4665
	Significance (2-Tailed)	0.0901	0.5878	0.7422
	N	149	149	149
	Analysis	Not Sig	Not Sig	Not Sig
Collaborative	Pearson Correlation	0.4010	0.4237	0.5506
	Significance (2-Tailed)	0.8235	0.1324	0.0483
	N	149	149	149
	Analysis	Not Sig	Not Sig	Significant
Integration	Pearson Correlation	0.3766	0.4441	0.4869
	Significance (2-Tailed)	0.1809	0.8941	0.9074
	N	149	149	149
	Analysis	Not Sig	Not Sig	Not Sig

Table 13 presents the significant relationship between the virtual laboratory and the students' learning outcomes in terms of Knowledge Acquisition, Skill Development, and Engagement. Since the computed p-values for most indicators are greater than the alpha value of 0.05, the null hypothesis stating that "There is no significant relationship between the virtual laboratory and the students' learning outcome" is accepted. This indicates that the use of virtual laboratories does not have a statistically significant relationship with students' learning outcomes.

However, the collaborative aspect of virtual laboratories demonstrated a significant relationship with engagement ($p = 0.0483$), suggesting that peer interaction and cooperative learning activities within the virtual lab contribute to students' motivation and participation. These findings align with Steinert (2022), who emphasized that collaborative learning enhances engagement by fostering teamwork, idea exchange, and active participation in the learning process. This implies that strengthening the collaborative features of virtual laboratories may further improve student engagement and create a more effective learning environment.

Test of Effect between using guided inquiry strategies through virtual laboratory and the students' performance

To test the significant effect between the virtual laboratory and the students' performance in terms of the Written Test and Assessment Task, they were treated statistically using Real Statistics Data Analysis Tools using the Regression Analysis.

Table 14 presents the significant effect of the virtual laboratory and students' performance in terms of the Written Test and Performance Task. Since the computed significance value ($p = 0.0000$) is less than the alpha level of 0.05, the null hypothesis stating that "There is no significant effect between the virtual laboratory and students' performance" is rejected. This indicates that the virtual laboratory has a statistically significant effect on students' performance.

Specifically, interface complexity ($\beta = 0.29$, $p = 0.0016$) in the written test and integration ($\beta = 0.3073$, $p = 0.0008$) in the performance task demonstrated the strongest contributions. This reveals that a well-structured, user-friendly virtual lab interface enhances students' ability to process and apply theoretical concepts in assessments. Likewise, seamless

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integration of virtual labs into the curriculum significantly improves hands-on learning and skill application in performance tasks.

TABLE 14. Significant effect between using guided inquiry strategies through virtual laboratory and the students' performance

Guided Inquiry Strategies Through Virtual Laboratory	Students' Performance	Beta Coefficients	t-value	P-value
Simulation	Written Test	0.0959	0.1317	1.374
	Performance Task	0.1417	1.654	0.1003
Interactivity Level	Written Test	0.161	1.6576	0.0996
	Performance Task	0.1111	1.2803	0.2025
Interface Complexity	Written Test	0.29	3.2118	0.0016
	Performance Task	0.1074	1.3312	0.1852
Collaborative	Written Test	0.0124	0.1196	0.9049
	Performance Task	0.1187	1.2802	0.2025
Integration	Written Test	0.1558	1.5586	0.1213
	Performance Task	0.3073	3.4411	0.0008

These findings align with Wennett (2023), who emphasized that effective digital learning environments improve student engagement and performance by reducing cognitive load and enhancing interactivity. This implies that refining virtual lab interfaces and ensuring their integration into the curriculum can further optimize students' academic success.

To complement the quantitative findings, interviews revealed that students found guided inquiry in virtual labs helpful for understanding environmental science, staying engaged, and applying concepts. They highlighted improved critical thinking and real-world connections, supporting the effectiveness of virtual labs in enhancing learning and performance.

IV. Conclusion and Recommendations

Based on the findings of this study, the following conclusions were drawn regarding the relationship and effectiveness of guided inquiry strategies through virtual laboratories in enhancing students' learning outcomes and performance in environmental science education.

The study established that there is no significant relationship between the use of guided inquiry strategies through virtual laboratories and students' overall learning outcomes. Thus, the posited null hypothesis is accepted. This indicates that while students showed positive perceptions and demonstrated improvements in engagement, knowledge acquisition, and skill development, these were not statistically linked to the guided inquiry strategy in a measurable way.

However, the study found that specific components of guided inquiry strategies have a significant effect on students' performance in written and practical tasks. In particular, Interface Complexity was positively associated with better Written Test performance, suggesting that a well-designed and navigable interface enhances students' cognitive understanding. Additionally, Integration significantly influenced Performance Task scores, indicating that the seamless incorporation of virtual laboratories into instructional content effectively supports students' practical application of theoretical knowledge. Therefore, the null hypothesis is partially rejected in this aspect, highlighting the importance of these components in improving performance-based assessments.

Based on the findings of this study, the following recommendations are proposed to enhance the effectiveness of virtual laboratories and guided inquiry strategies in environmental science education:

Teachers and instructional designers may be provided with exemplar modules and training that embed inquiry prompts and problem-solving scenarios within the virtual lab sessions to ensure effective implementation of guided inquiry strategies.

Curriculum developers and educators may pair virtual labs with active learning techniques such as prediction tasks, exploration cycles, and debriefing sessions to enhance student engagement and support deeper conceptual understanding.

Future researchers may investigate moderating factors such as students' prior knowledge, motivation, learning styles, or even the subject complexity.

School administrators may therefore expand access to these tools, particularly in resource-constrained contexts where physical lab access is limited.

Program evaluators and Management Information System (MIS) may regularly collect assessments and student feedback to identify specific areas for improvement in virtual laboratory design and implementation, ensuring alignment with students' needs and curricular goals.

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