e-ISSN: 3031-6391
p-ISSN: 3026-0140

Content lists available at Indonesia Academia Research Society

International Journal of Industrial Engineering, Technology & Operations Management

Journal homepage: ejournals.indoacademia-society.com/ijietom

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Original Article

Development of a Method to Enhance the Efficiency of Establishing VR Educational Laboratories

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Article History
Received: 27 August 2024
Revised: 19 November 2024
Accepted: 9 December 2024
Available Online: 31 December 2024

Keywords:
Virtual reality
Fibonacci sequence
Learning efficiency
Cognitive adaptation
Student health

Abstract
This study investigates the development of an efficient method for establishing virtual reality (VR) educational laboratories, focusing on enhancing teaching outcomes in technical fields exemplified through English classes. The integration of VR in technical education has been proven to improve learning efficiency, with studies showing a learning rate increase of 75-90% and a knowledge acquisition speed of up to four times faster. Despite these benefits, prolonged VR exposure can result in discomforts such as dizziness, eye strain, and cognitive fatigue. This study proposes a Fibonacci-based approach to structure VR learning sessions to address these challenges. By organizing session intervals according to the Fibonacci sequence and incorporating structured breaks, this method supports optimal cognitive processing, minimizes physical discomfort, and allows for smoother transitions between the virtual and real environments. A practical experiment involving 24 students was conducted to evaluate the effectiveness of this approach. The results revealed statistically significant improvements in learning outcomes and adaptation compared to traditional continuous VR sessions, with a p-value of less than 0.05. These findings suggest that the Fibonacci-based method offers a promising solution to the challenges associated with extended VR exposure in educational settings, enabling more effective and comfortable learning experiences. This approach holds potential for broader application in various technical fields, where VR serves as a tool for enhancing educational outcomes.

1. Introduction

Today, virtual reality (VR) technologies in teaching technical subjects are gaining rapid momentum (Dede et al., 1997). Research indicates that VR-based laboratories significantly enhance learning outcomes, with comprehension rates reaching 75-90% and the pace of mastering the material accelerating up to four times compared to traditional methods (Bilen, 2018; Malik, 2020; Samar Qorbani, 2023). It undoubtedly provides significant benefits for teaching technical subjects. However, in many educational institutions, laboratory and practical classes based on VR technology are conducted continuously, meaning the laboratory session proceeds without interruption until the set task is completed.

Most VR-based laboratory models are designed in this manner. In this case, students completing a virtual laboratory session for the first or second time often experience dizziness and, in some cases, nausea (Alnagrat et al., 2022).

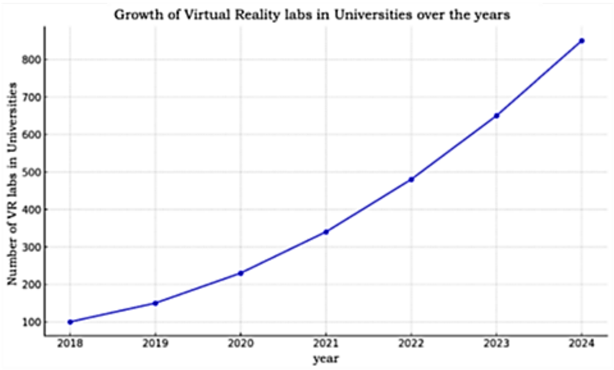

Figure 1. Growth of Virtual Reality labs in Universities over the year

For students who have acquired the necessary skills to perform laboratory tasks using VR technology, It prolonged engagement in the laboratory, practical results in eye fatigue, and a brief period of adjustment when transitioning from the virtual world to real life. These advancements underscore the effectiveness of VR in educational settings, making it a valuable tool for modern learning environments (see Figure 1) (Caroline, 2024; Aneesh, 2024).

In response to these issues, a virtual reality laboratory and practical class were developed for students, structured according to the Fibonacci proportion method. This approach was used to assess the degree of students' adaptation from real life to virtual environments and back, aiming to minimize discomfort and improve the overall learning experience.

2. Literature Review

2.1. VR in Training and Education

Caroline (2024) explores whether VR training is more efficient than traditional learning methods, highlighting VR's potential to create immersive, engaging learning environments that may boost retention and understanding (FrontCore). Aneesh (2024) emphasizes VR's transformative role in corporate skills training, particularly in creating realistic, hands-on experiences that can accelerate employee learning (Chief Learning Officer). Doug (2024) provides insights into ten case studies where VR was successfully applied to enhance training effectiveness, suggesting VR's capacity to make training more impactful and memorable (Interplay Learning).

2.2. Fibonacci Sequence in Nature and Learning.

Elias (2024) discusses the influence of the Fibonacci sequence in natural patterns, underscoring how this mathematical marvel appears in human and natural forms, possibly inspiring new educational approaches (Medium). Sacco (2018) expands on the synchronistic role of Fibonacci harmonics in various natural phenomena, suggesting mathematical models to explain these patterns (Applied Mathematics). Kaygin et al. (2011) study the effect of teaching Fibonacci numbers through historical context, revealing how contextual learning can improve comprehension in mathematical topics (Procedia - Social and Behavioral Sciences). Additionally, Ravindra and Rengan (2022) review the Fibonacci sequence's appearance in human anatomy, specifically in the abdominal wall, reinforcing the sequence's relevance to both biology and mathematics (Cureus). This collection of studies demonstrates both the potential of VR in modern training and the educational value of the Fibonacci sequence, underscoring immersive technology and mathematical principles as powerful tools for enhancing learning experiences across diverse fields.

3. Materials and Methods

This study employed a comparative experimental design to evaluate the effectiveness of a Fibonacci-structured VR laboratory approach against a traditional, continuous method. Twenty-four students were divided equally into two groups: one using the traditional method and the other using Fibonacci-based intervals for VR sessions. Quantitative data on student performance, adaptation, and comfort were collected and statistically analyzed using an independent t-test to assess the significance of differences between groups.

This study is structured into sections, including a literature review, development of teaching stages, structured lesson processes, and statistical analysis. Figures and tables were used to visually represent the growth of VR labs, time distribution based on the Fibonacci sequence, and lesson breakdown, supporting a clear, concise presentation of findings and conclusions (Figure 2).

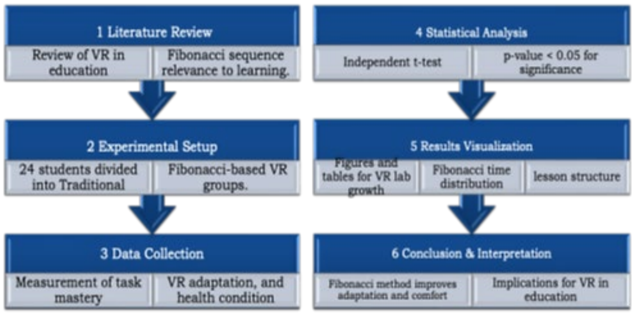

Figure 2. A flowchart of the study design and methodology

4. Results and Discussions

4.1. Development of Teaching Stages

Human anatomy and growth processes have been determined to follow the Fibonacci sequence (1, 1, 2, 3, 5, 8, ...). From a mathematical point of view, the properties of the Fibonacci sequence have been used to develop models such as the Fibonacci Life Chart Method (FLCM). This model attempts to depict the stages of human development based on these numbers. It asserts that each Fibonacci number represents a full 24-hour cycle, highlighting human growth and development's rhythmic and cyclical nature (Elias, 2024). Research has also shown that structuring learning intervals according to the Fibonacci sequence significantly enhances the brain's ability to learn new information and adapt to new environments more easily (Sacco, 2018; Kaygin et. Al., 2011).

Based on this, organizing learning time intervals per the Fibonacci sequence offers an effective solution for improving students' learning outcomes and safeguarding their health. Additionally, 2-5 minutes breaks are incorporated within each time interval. The importance of these short, targeted sessions is that the proposed sequence gradually increases the duration of each VR laboratory session, focusing on shorter but more intensive cognitive learning activities. Research on brain training shows that dividing training into shorter sessions prevents mental fatigue and enhances focus, leading to better retention and learning (Ravindra et al., 2022).

Furthermore, the information covered during the VR laboratory session is divided into seven levels based on complexity. During the designated 80-minute practical session, students are introduced to the first level, which includes introductory information and tasks to be completed at the end of the session. In the second level, students familiarize themselves with the objectives and tasks of the practical tasks. At the third level, students adjust the VR goggles to fit their eyes, and in the fourth level, they calibrate the sensors for their neck and hand movements. The actual execution of the laboratory tasks takes place in levels five to seven, where tasks are divided based on their complexity. The final 72-80 minutes of the review and assessment session are spent on levels two through four, during which time the issues encountered in the practical part are analyzed with students, and knowledge is reinforced through a Q&A format (Figure 3).

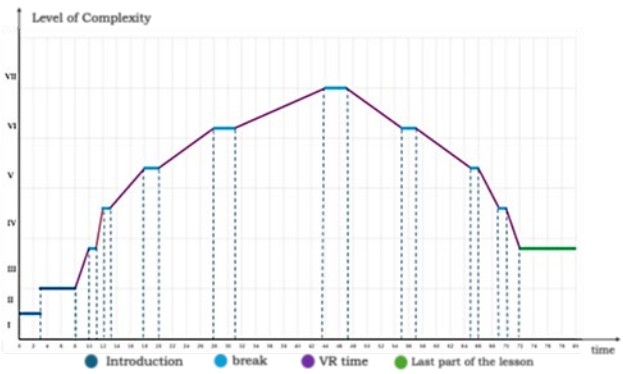

Figure 3. The Distribution of Time Based on the Fibonacci Proportion for Performing Laboratory Tasks and Its Relation to the Complexity of the Material

4.2. Structured Lesson Processes

The lesson process facilitates students' gradual adaptation to the virtual reality (VR) environment, while optimizing cognitive load and reducing potential fatigue through structured breaks. Below is the scientifically organized sequence (Table 1):

Introduction to Session (3 minutes). This initial phase introduces students to the VR laboratory environment and outlines the session's objectives, providing an essential orientation to ensure that students are mentally prepared for the VR activities. Warm-up (5 minutes). A preparatory warm-up period helps students acclimate mentally and physically to the VR experience. This phase encourages relaxation and mental focus, setting a foundational state for engagement in VR tasks.

Class Overview (2 minutes). This phase provides an overview of the specific VR tasks and learning outcomes expected from the session. Break - Progress Review (1 minute). A brief pause allows students to observe their initial progress, maintaining focus without overwhelming cognitive resources. Visual Adaptation for VR (3 minutes). Students spend time adjusting their VR goggles for optimal visual alignment and comfort, reducing the risk of eye strain during subsequent tasks.

Break - Comfort Check (1 minute). A short break for students to evaluate their visual comfort, ensuring optimal readiness for continued VR immersion. Physical Adaptation for VR (5 minutes). In this stage, students adapt their body movements within the VR space, including sensor calibration for neck and hand movements, promoting ease of physical interaction within the virtual environment.

Break - Physical Comfort Check (2 minutes). A pause allows students to assess their physical adaptation, mitigating potential symptoms of discomfort, such as dizziness or nausea. Pre-task in VR Environment (8 minutes). Introductory VR tasks are presented in this initial session, allowing students to become familiar with the environment through simple activities that serve as a foundation for more complex tasks.

Break - Progress Assessment (3 minutes). A review period encourages students to process and internalize initial experiences, supporting preparation for more advanced tasks in the following stages. Primary Task Activity (13 minutes). This is the core component of the session, where students engage in the primary, complex VR tasks that require focused effort and application of prior knowledge. Break - Task Reflection (3 minutes). A strategic pause enables students to reflect on their task performance, reinforcing memory retention and preventing cognitive fatigue.

Post-task Review and Application (8 minutes). This follow-up activity consolidates the primary tasks completed, reinforcing learning outcomes and encouraging students to apply what they have practiced in a new context. Break - Final Progress Review (2 minutes). A brief pause for students to observe their overall progress, aiding the transition from intensive VR activities to the session's concluding stages. Session Conclusion (5 minutes). This phase wraps up the session by summarizing key takeaways, providing students with a structured review of the knowledge and skills acquired.

Break - Transition to Real-world Application (2 minutes). A final break introduces any homework, allowing students to transition from the VR session to real-world application mentally—assessment Phase (3 minutes). A short assessment gauges student comprehension and retention, offering immediate feedback on their progress and reinforcing learning outcomes. The structured sequence of activities and breaks, organized according to the Fibonacci proportion, enhances student engagement and comfort. The intervals are carefully chosen to support cognitive processing and prevent the physical and mental fatigue typically associated with prolonged VR sessions. This methodology leverages natural cognitive rhythms, promoting effective learning and adaptation within the VR laboratory environment.

Table 1. Structured Lesson Sequence with Fibonacci-Based Break Intervals for VR Laboratory

Level	Process of Lesson	Break Time	Lesson Time
I	Starting class		3min
II	Warm up		5min
III	Introduction of the class		2min
Break	Watching result	1min	
IV	Adapting eyes for VR		3min
Break	Watching result	1min	
V	Adapting body to the VR		5min
Break	Watching result	2min	
VI	Starting VR with pre-task		8min
Break	Watching result	3min	

VII	Main task activity		13min
Break	Watching result	3min	
VI	Post -task		8min
Break	Watching result	2min	
V	Conclusion		5min
Break	Homework	2min	
III	Assessment part		3min

4.3. Empirical Results

In this study, 24 students were selected and divided equally into two groups. One group of 12 students performed laboratory tasks using the traditional, continuous method, while the other 12 students carried out the tasks using a proposed method based on the Fibonacci proportion. The students were assessed in terms of mastering the laboratory tasks, their adaptation to the VR laboratory environment, and their health condition during the process. The experiment is ongoing, and the first phase has been completed. The results obtained from this phase were statistically analyzed using a t-test, which yielded a value of p=$8.85 \cdot 10^{-10}$. Since this value is less than 0.05, it suggests that the proposed method is effective. The following table shows the scores for each student in both groups (Table 2)

Table 2. Structured Lesson Sequence with Fibonacci-based break Intervals for VR Laboratory

Students	Group 1 (Traditional)	Group 2 (Fibonacci)
1	78	85
2	74	88
3	82	90
4	80	92
5	76	87
6	81	89
7	79	91
8	77	86
9	75	90
10	80	93
11	78	88
12	82	92

The steps for analyzing the t-test results are as follows:

4.3.1. Proposed Hypotheses

Null Hypothesis (H0): There is no difference between the traditional and modern VR laboratory methods. Alternative Hypothesis (H1): There is a difference between the traditional and modern VR laboratory methods.

4.3.2. Determine test statistics

Since we are comparing the means of two groups, an independent (two-sample) t-test is applied.

4.3.3. Apply the Formula

For an independent t-test, the t-statistic is calculated as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (1)$$

Where: $\bar{X}_1$ and $\bar{X}_2$: the means of the two groups, S_1^2 and S_2^2: the variances of the two groups, n_1 and n_2: the sample sizes for each group (12 in this case). Using the data provided: Mean for Group 1 (Traditional): $\bar{X}_1 = 78.33$, Mean for Group 2 (Fibonacci): $\bar{X}_2 = 89.42$, Variance for Group 1: $S_1^2 = 5.06$ and Variance for Group 2: $S_2^2 = 5.24$.

$$S_1^2 = \frac{\sum(X_i - \bar{X}_1)^2}{n_1 - 1} \quad (2)$$

$$S_1^2 = \frac{\sum(X_i - \bar{X}_2)^2}{n_2 - 1} \quad (3)$$

4.3.4. Calculate the Degrees of Freedom

The degrees of freedom (df) are calculated as:

$$df = n_1 + n_2 - 2 \quad (4)$$

In this case:

$$tdf = 12 + 12 - 2 = 22 \quad (5)$$

4.3.5. Compare the t-stats and p-value

Using the calculated t-statistic and p-value, we can decide to accept or reject the null hypothesis. In this case, $p = 8{,}75 \cdot 10^{-10}$, which is less than 0.05, indicating a statistically significant difference.

4.3.6. Interpretation

Since p<0.05, we reject the null hypothesis. This indicates a significant difference between the traditional and VR laboratory methods, showing the proposed method's effectiveness.

5. Conclusions

The Fibonacci-based approach to structuring VR laboratory sessions offers a promising solution to the challenges of continuous VR exposure in educational settings. Utilizing time intervals that follow the Fibonacci sequence allows students to gradually adapt to the VR environment while maintaining focus and minimizing physical discomfort. Short, structured breaks based on the Fibonacci intervals provide necessary pauses for mental and physical recovery, enhancing learning retention and preventing fatigue. The results of the practical experiment indicate that this structured approach not only improves students' performance on VR tasks but also supports healthier adaptation to VR. This method can be valuable for a wide range of technical education applications and may benefit other fields where VR is used as a training tool. Further research could explore its effectiveness in long-term learning outcomes and its application across different disciplines.

Author Contributions: Conceptualization, R.I. and T.R.; methodology, R.I.; software, R.I.; validation, T.R.; formal analysis, R.I. and T.R.; investigation, R.I. and T.R.; resources, R.I; data curation, T.R.; writing—original draft preparation, R.I.; writing—review and editing, R.I. and T.R.; visualization, R.I.; supervision, T.R.; project administration, T.R.; funding acquisition, T.R. The author has read and agreed to the published version of the manuscript.

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Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Inform Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: The author would like to thank Oriental University, Uzbekistan, for supporting this research and publication. We also thank the reviewers for their constructive comments and suggestions.

Conflicts of Interest: The author declares no conflict of interest.

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