

THE IMPACT OF VIRTUAL REALITY(VR) SIMULATION ON WAREHOUSE LOGISTICS EDUCATION: A CASE STUDY OF DIPLOMA IN LOGISTIC AND SUPPLY CHAIN STUDENTS

Suliza Binti Othman*¹, Dinie Syuhada Binti Anuar²

¹Seberang Perai Polytechnic, Malaysia

²BYD Electronics (M) Sdn Bhd, Operation Department, Malaysia

*Corresponding email: suliza@psp.edu.my

ABSTRACT

The rapid evolution of the Fourth Industrial Revolution necessitates a paradigm shift in vocational education, particularly in logistics and supply chain management. Addressing the limitations of traditional and theory-heavy teaching methods, this quantitative study investigates the efficacy of 'VirtuLogix' a 360-degree virtual reality simulation tool, on diploma students enrolled in logistics and supply chain courses. The research adopted a pre-experimental, one-group pretest and post-test quantitative design to measure operational competencies. Data was collected from a sample of twenty-three students using a structured five-point Likert scale instrument before and after the virtual reality intervention. Inferential statistical analysis, including paired-sample testing, revealed highly significant improvements across all measured competencies. Furthermore, effect size analysis revealed very large practical effects, indicating a substantial educational impact. The findings strongly support that virtual reality simulation is a cost-effective and safe pedagogical tool that successfully bridges the gap between theoretical knowledge and practical industrial application. By providing a hands-on experience that is deeply immersive, the simulation served as an interactive teaching and learning tool that simplifies the explanation of complex technical skills. Ultimately, this approach significantly reduced the financial budget required for student transportation to physical industrial sites and eliminated the safety risks associated with bringing large student groups into active operational warehouse.

Keywords: Virtual Reality, Warehouse Management, Logistics Education, Immersive Learning, Simulation

1. INTRODUCTION

Warehouse logistics education plays a fundamental role in equipping students with industry-relevant competencies, including inventory control, spatial optimization, and operational fluidity. However, conventional pedagogical frameworks in Technical and Vocational Education and Training (TVET) tend to rely heavily on theoretical instruction, which limits students' opportunities to acquire practical skills required in modern logistics environments. One of the primary challenges in this field is the restricted access to physical warehouse facilities, often caused by high operational costs, safety concerns, and geographical constraints. As a result, students frequently encounter difficulties in visualizing complex logistics processes, leading to a gap between theoretical understanding and practical application.

In response to these challenges, Virtual Reality (VR) has emerged as a transformative educational technology. By creating immersive and interactive environments, VR enables

learners to engage in realistic simulations without exposure to physical risks. This study introduces VirtuLogix, a VR-based platform specifically designed to enhance spatial awareness, workflow efficiency, and financial understanding within warehouse logistics education. Through this approach, students are expected to gain a more comprehensive and applied understanding of logistics operations.

Logistics students often face significant challenges in visualizing large-scale warehouse operations due to limited access to real-world facilities. In addition, understanding the financial implications of operational decisions, such as picking path optimization, remains difficult without real-time feedback mechanisms. Although existing studies have widely explored VR as a tool to enhance student engagement, there is still a lack of empirical research examining its comprehensive impact on operational performance metrics within vocational logistics education. Addressing this gap, the present study proposes a novel pedagogical framework by simultaneously evaluating three key variables: spatial layout optimization, workflow efficiency based on lean principles, and real-time financial visualization within a single immersive VR environment. By explicitly linking operational decisions to economic outcomes, this study positions VR not merely as an experiential learning tool, but as a data-driven medium for strategic and cost-based decision-making in a TVET context.

Accordingly, this study aims to identify optimal warehouse space utilization through simulated VR layouts, evaluate the effectiveness of VR in enhancing workflow efficiency and minimizing non-value-added activities, and assess the extent to which VR visualization improves students' understanding of cost reduction and financial implications. These objectives are designed to provide a comprehensive evaluation of VR integration in logistics education.

In line with these objectives, this study is guided by several research questions that examine whether VR simulation significantly improves spatial awareness in warehouse layout design, enhances workflow efficiency by reducing idle movement, and strengthens financial decision-making in logistics operations. These questions serve as the basis for determining the effectiveness of VR as an instructional and analytical tool in vocational education.

From a theoretical perspective, contemporary research recognizes Virtual Reality as a transformative catalyst in simulation-based learning environments. Studies indicate that VR enhances learning engagement by providing immersive experiences that stimulate both visual and kinaesthetic learning modalities. In the context of logistics education, platforms such as VirtuLogix align with Constructivist Learning Theory, which emphasizes experiential learning as a means to bridge the gap between theory and practice. Furthermore, VR-based training has been shown to reduce operational costs while functioning as a digital twin of real-world systems, allowing learners to experiment with complex scenarios in a controlled environment.

Moreover, active engagement plays a critical role in cognitive processing. Traditional passive learning approaches are often insufficient for fostering deep understanding, particularly in complex domains such as logistics. VR transforms students into active participants in the learning process, which is closely associated with improved motivation, retention, and problem-solving capabilities. These factors are essential for mastering intricate logistics concepts and for preparing students to meet the demands of the modern logistics industry.

2. METHODOLOGY

A quantitative pre-experimental design (one-group pretest and post-test) was employed to evaluate the impact of the VR intervention. Using purposive sampling, the study involved Diploma in Logistics and Supply Chain students from Politeknik Seberang Perai. Data were collected using a structured 5-point Likert scale questionnaire measuring spatial awareness,

workflow efficiency, and financial understanding. Reliability analysis confirmed high internal consistency (Cronbach's Alpha). Data were processed using SPSS, utilizing paired-sample t-tests and Cohen's to determine statistical significance and effect size.

3. RESULTS

The results of the study based on the analysis of pre-test and post-test data across eight key constructs, namely financial visualization, cost reduction, safety risk mitigation, resource allocation, picking path design, reducing idle movement, process sequencing, and time management. The analysis focuses on comparing mean scores and standard deviations to examine changes in participants' competencies before and after the implementation of the intervention. As summarized in Table X, the findings reveal a consistent improvement across all measured constructs, indicating that the intervention contributed positively to enhancing students' understanding and performance in warehouse logistics operations.

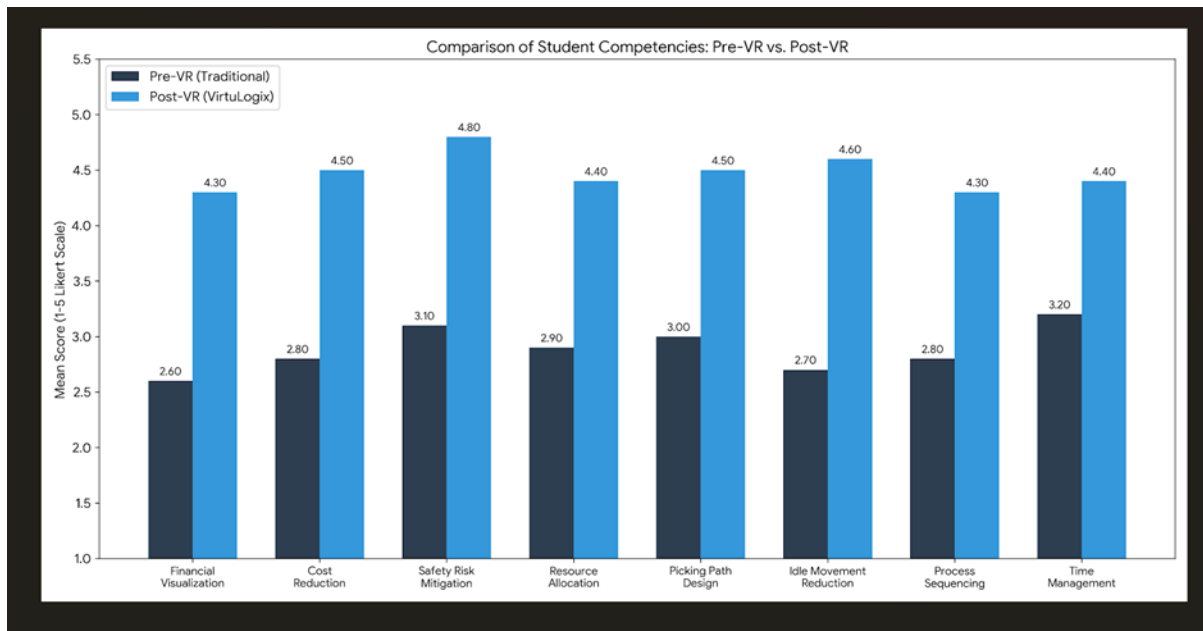
Table 1. Paired Samples Statistics

Construct	Mean (Pre)	SD (Pre)	Mean (Post)	SD (Post)	N
Financial Visualization	2.60	0.55	4.30	0.50	23
Cost Reduction	2.80	0.58	4.50	0.48	23
Safety Risk Mitigation	3.10	0.60	4.80	0.41	23
Resource Allocation	2.90	0.57	4.40	0.52	23
Picking Path Design	3.00	0.54	4.50	0.50	23
Reducing Idle Movement	2.70	0.55	4.60	0.49	23
Process Sequencing	2.80	0.56	4.30	0.53	23
Time Management	3.20	0.52	4.40	0.50	23

Table 2: Paired Samples Test & Effect Size (Cohen's d)

Construct	Mean Diff	t	df	Sig.(2-tailed)	Cohen's d	Interpretation
Financial Visualization	1.70	11.82	22	.000	2.46	Very Large
Cost Reduction	1.70	11.95	22	.000	2.49	Very Large
Safety Risk Mitigation	1.70	11.38	22	.000	2.37	Very Large
Resource Allocation	1.50	10.42	22	.000	2.17	Very Large
Picking Path Design	1.50	10.65	22	.000	2.22	Very Large
Idle Movement Reduction	1.90	13.12	22	.000	2.73	Very Large
Process Sequencing	1.50	10.21	22	.000	2.13	Very Large
Time Management	1.20	9.18	22	.000	1.91	Very Large

The paired-sample t-test results indicate statistically significant improvements across all measured constructs ($p < .001$). The largest improvement was observed in reducing idle movement ($t=13.12$), followed by cost reduction and financial visualization. The confidence intervals did not cross zero, confirming the robustness of the findings. Furthermore, effect size analysis revealed very large effects indicating that the VR intervention had a substantial practical impact on students' competencies. Hypotheses H1, H2, and H3 are firmly supported.



Picture 1. Comparison of Pre-VR and Post-VR Mean Scores Across All Competency Constructs

The chart illustrates a dramatic increase across all measured variables, with 'Idle Movement Reduction' and 'Safety Risk Mitigation' showing the most significant leaps post-intervention. Scores are based on a 5-point Likert scale.

4. DISCUSSION

The empirical findings of this study demonstrate that the VirtuLogix VR simulation significantly enhances warehouse management competencies. More importantly, these results strongly corroborate existing theoretical frameworks as well as recent empirical studies on immersive learning within vocational education. The overall improvement observed across multiple constructs indicates that VR-based interventions are not only effective in facilitating technical understanding but also in bridging the gap between theoretical knowledge and practical application in logistics education.

One of the most prominent cognitive shifts identified in this study is the improvement in spatial awareness, particularly in students' ability to conceptualize three-dimensional warehouse layouts, as reflected in a mean increase of 1.80. From the perspective of Cognitive Load Theory, traditional instructional tools such as two-dimensional warehouse blueprints impose a high level of extraneous cognitive load on learners. As a result, students tend to expend significant mental effort merely to visualize spatial depth and structure, rather than focusing on analyzing operational efficiency. The implementation of VirtuLogix effectively mitigates this limitation by providing an immersive, first-person perspective that transfers the burden of spatial processing to the visual system. This finding aligns with previous studies suggesting that immersive VR enhances visual and kinesthetic engagement, thereby allowing learners to allocate more cognitive resources toward higher-order analytical tasks such as identifying bottlenecks and optimizing storage configurations. Furthermore, the observed improvement supports the concept of embodied cognition, where knowledge is constructed through direct interaction with the environment. Unlike static representations, VR enables real-time navigation within warehouse layouts, enhancing spatial reasoning while reducing abstraction.

In addition to spatial awareness, a substantial improvement was observed in workflow efficiency, particularly in reducing idle movement, which recorded the highest statistical gain. This finding strongly supports Experiential Learning Theory, which emphasizes the importance of concrete experience and active experimentation in achieving meaningful learning outcomes. Conventional passive learning approaches often fail to effectively convey the principles of lean logistics, as students are unable to directly experience the consequences of inefficient operational design. Through the VirtuLogix simulation, students were able to virtually navigate warehouse environments, transforming their role from passive observers into active participants. This immersive experience enabled them to directly perceive inefficiencies, such as suboptimal picking paths, and understand their impact on operational performance. As a result, students were able to construct more effective and optimized workflow strategies based on experiential insight rather than theoretical memorization.

Another significant contribution of this study lies in the integration of operational activities with financial visualization. Traditionally, logistics education tends to treat physical operations and cost analysis as separate domains. However, the findings reveal a marked improvement in students' understanding of financial implications, particularly in relation to cost reduction and safety risk mitigation. The VR simulation environment enabled students to observe the direct consequences of operational decisions, such as inefficient handling processes or safety violations, in terms of financial loss and liability. This experiential linkage between action and outcome transforms abstract economic concepts into tangible learning experiences. By functioning as a high-fidelity simulation environment, the VirtuLogix platform allows students to experiment with different operational strategies and immediately observe their economic impact, thereby fostering more informed and strategic decision-making without exposure to real-world risks.

Despite these contributions, several limitations should be acknowledged. The study is constrained by a relatively small sample size and the absence of a control group, which may affect the generalizability of the findings. Furthermore, the short duration of data collection limits the ability to assess long-term learning retention and behavioral change. Nevertheless, this study offers both theoretical and practical contributions by demonstrating how VR can integrate spatial cognition and operational cost analysis within a single learning framework. From a practical standpoint, it provides TVET institutions with a scalable and cost-effective alternative to traditional industrial training methods, reducing safety risks while enhancing the quality of instructional delivery. Future research is recommended to employ experimental designs with larger sample sizes and longitudinal approaches to evaluate sustained learning outcomes, as well as to explore the integration of artificial intelligence within VR platforms to support adaptive and personalized learning experiences.

5. CONCLUSION

The study confirms that VR-based simulation significantly enhances key competencies in logistics education, particularly in spatial awareness, workflow efficiency, and financial understanding. In the context of ongoing digital transformation, the integration of VR technology represents a critical advancement in modern TVET pedagogy rather than an optional enhancement.

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