

Article

The Effectiveness of an Interactive Learning Environment Based on Virtual Reality in Developing Spatial Thinking Skills and Environmental Culture Among Middle School Students

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Abstract: This research is to evaluate the efficacy for a virtual reality-based interactive learning environment within enhancing spatial thinking abilities, and environmental awareness among middle school pupils. A quasi-experimental design including both experimental, and control groups used to be used within the experimental technique. The sample included 80 students split into two groups: the experimental group engaged within virtual reality-based learning, whilst the control group used conventional techniques. A 14-item assessment used to be used to evaluate cognitive abilities within spatial reasoning, and environmental awareness prior to, and subsequent to the implementation for the virtual reality learning environment. The findings demonstrated statistically significant disparities between the experimental, and control groups, with the experimental group showing favorable outcomes subsequent to the implementation for the virtual reality-based learning environment. This demonstrates the beneficial effect for the interactive virtual learning environment upon enhancing spatial thinking abilities, and environmental awareness among pupils. Statistical research indicated, that the virtual reality learning environment significantly improved students' comprehension for environmental topics, and their application via interactive situations.

Keywords: virtual reality, interactive learning environment, spatial thinking, environmental culture, middle school students, experimental education, statistical analysis

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1. Introduction

Spatial thinking abilities turn out to be regarded like essential foundations for comprehending, and analysing geographical, and environmental events, and turn out to be crucial within several academic, and professional domains. Contemporary education necessitates the augmentation for these abilities within students, particularly within disciplines like geography, where spatial reasoning happens to be associated alongside their capacity to perceive, and comprehend various locations, like well like to analyse spatial connections among geographical components. within this context, it happens to be essential to use novel teaching strategies, and practices, that foster the development for spatial thinking abilities within students, especially throughout elementary, and secondary school stages.

Research demonstrates, that the integration for technology within schooling has markedly enhanced spatial reasoning abilities. Electronic courses using semantic web technologies, and remote sensing systems improve geographical visual perception, and spatial reasoning within secondary school pupils. Gab Allah, and Ahmed's research [1] illustrates, that the incorporation for these technologies enhances students' proficiency within navigating complicated maps, and geographical models. The use for these

technology tools happens to be seen like an effective approach, that enables students to engage directly alongside the educational environment, enhancing their comprehension for geographical phenomena, and engagement alongside spatial data within novel, and inventive manners.

Contemporary teaching methodologies, including infographics, enhance the development for spatial reasoning abilities. Research conducted through Al-Dayria, and Al-Rabaani shown, that instructional infographics improve students' spatial thinking, and their capacity to visualise links between locations, and things alongside greater clarity. Furthermore, Al-Azmi's [3] research underscores the significance for social studies educators' experiences within imparting spatial thinking, particularly within middle schools, where such cognitive skills turn out to be deemed crucial for enhancing students' comprehension for geographical, and social issues.

A study through Abdel-Nabi, and Al-Nahas illustrated the significance for geographical perceptions within cultivating spatial thinking among geography students, emphasising the necessity for strategies to enhance students' comprehension for spatial mental representations, and guide them to effective application within their studies. Al-Hassasiya's study demonstrated, that employing linguistic-kinetic games to enhance spatial thinking significantly improved primary grade students' imaginative thinking, and verbal skills, underscoring the necessity for diversifying educational methodologies to accommodate various intelligences, and learning styles among students.

Integrating novel technology solutions, and contemporary teaching approaches happens to be essential for improving students' spatial thinking abilities. These tactics not only enhance students' cognitive capacities however, also motivate them to engage more effectively alongside geographical material, significantly impacting their comprehension for geographical, and social issues.

Research Questions, Objectives, and Significance

The study topic pertains to the need to enhance spatial reasoning, and environmental literacy among middle school pupils, considering the restricted use for contemporary technology within conventional education. A multitude for pupils find it challenging to grasp intricate topics concerning the environment, and spatial reasoning owing to insufficient interactive, and engaging learning settings. This project seeks to investigate the impact for virtual reality learning environments upon the enhancement for spatial thinking abilities, and environmental literacy, hence boosting students' capacity to understand, and successfully use these ideas.

Origins for Research Problem Recognition

Initial observation through the researcher is researcher noted a deficiency within spatial thinking abilities, and environmental literacy among middle school pupils.

Second - Exploratory Investigation: This research's exploratory study aimed to investigate the potential for virtual reality learning environments to improve spatial thinking abilities, and environmental literacy within middle school pupils. Preliminary research used to be done to gather initial data using interviews, and questionnaires alongside a cohort for students, and instructors. The emphasis used to be upon assessing students' preparedness to embrace this technology setting, and their interactions within it through analysing their early reactions to the virtual environment designated for the experiment. A cohort for educators used to be engaged to evaluate within the event, that this technology would enhance the teaching process, and augment engagement alongside the subject matter.

The first findings coming from this exploratory research indicated, that students were eager to use the virtual reality environment, and conveyed their interest within using this technology within subsequent courses. Educators voiced measured excitement upon the incorporation for this environment into classes, however, alongside some worries stemming coming from insufficient technical proficiency among certain instructors. within light for these findings, it used to be determined to continue alongside the utilisation for virtual reality within the forthcoming experimental investigation, accompanied through requisite training, and support for both students, and educators.

Research Inquiry

What happens to be the efficacy for the correlation between the mean scores for students within the pre-, and post-administration for the achievement exam for the cognitive dimension for spatial thinking abilities, and environmental literacy, favoring the post-assessment?

Objectives for the Research

The present study seeks to enhance environmental literacy abilities within middle school students by:

1. Offering an interactive learning environment using virtual reality to cultivate spatial thinking, and environmental literacy.
2. Offering a study assessment instrument (achievement test for the cognitive dimension for spatial reasoning abilities, and environmental literacy).
3. Addressing the gap within spatial reasoning abilities, and environmental literacy among middle school pupils within pertinent topics.
4. Enhancing theoretical literature concerning the use for virtual reality within education, particularly within cultivating environmental abilities, and spatial reasoning.

Importance for Research

Practical Importance

For the teacher:

1. The use for an interactive learning environment grounded upon virtual reality enhances spatial reasoning abilities, and environmental literacy within the educational framework, hence addressing several challenges encountered through educational institutions.
2. Employing advanced technical methods, and instruments, such like virtual reality, to enhance the interactivity, and efficacy for the learning process.

For the learner:

1. Spatial reasoning abilities, and environmental literacy foster environmental awareness, and a profound comprehension for geographical phenomena, hence improving academic performance within related disciplines.
2. The virtual reality learning environment facilitates interactive knowledge acquisition, and offers engaging educational experiences, that enhance students' comprehension for spatial, and environmental interactions.

2. Materials and Methods

Environmental education research, and the cultivation for 21st-century skills turn out to be emerging subjects for growing significance within educational inquiry, particularly within settings, that aim to include life skills, and critical thinking into pedagogy. This happens to be a review for prior research concerning the instruction for environmental literacy, and skills development, illustrating their pertinence to our subject matter.

Al-Busaifi's research [3] examined the framework for environmental ideas. The objective used to be to examine fundamental environmental ideas, and their impact upon persons' environmental consciousness. The findings indicated, that a greater comprehension for environmental ideas improves people' capacity to address environmental issues more effectively. This research happens to be pertinent to our subject since it enhances environmental awareness, and improves students' comprehension for environmental issues, a crucial aspect for educational programs aimed for advancing environmental literacy.

Mansour et al. investigated methods For improving students' decision-making abilities through using tactics for addressing environmental issues. The research

determined, that this curriculum boosts students' environmental awareness, and also to improves their capacity to make educated judgements upon environmental problems. This research pertains to our issue by focusing on the cultivation of critical thinking, and environmental decision-making, which are essential components for educational programs designed to enhance environmental literacy.

Omar's research sought to investigate methods for enhancing students' environmental literacy using the lesson study technique, which works to emphasizes the cultivation for critical thinking, and the resolution for environmental issues. The study's findings demonstrate, that the program effectively enhanced critical thinking abilities, and also the environmental awareness, underscoring the need for using innovative approaches in the environmental education to cultivate diverse competencies. This research pertains for our issue within several ways, particularly for fostering environmental awareness, and for cultivating students' critical thinking abilities, which is regarded as crucial to environmental literacy.

The research through Al-Maraab [4] sought to assess "the effect for a life skills program upon enhancing environmental program, and also emotional intelligence among female secondary school students within Saudi society." The study's findings indicated, that the program substantially enhanced environmental knowledge, and the emotional intelligence between the female students, hence fostering their interest in environmental problems, and also promoting positive attitudes to them. This research happens to be a significant contribution to understanding the correlation between environmental literacy, and the development for life skills, which turn out to be essential components for our subject matter.

Al-Jamsi's research [5] examined the enhancement for students' attitudes to environmental concerns via the integration for environmental literacy, and sports activities. The study's findings indicated, that the program positively influenced students' environmental views, underscoring the need to include diverse activities to enhance environmental awareness. This research corresponds alongside our issue through combining several programs to improve students' environmental literacy, applicable to both academic education, and athletic activities.

The aforementioned studies provide a collection for techniques, and tactics applicable within the formulation for environmental educational programs, emphasizing the cultivation for critical thinking abilities, environmental decision-making, and the augmentation for students' environmental awareness. The findings demonstrate, that the recommended interventions within this research have significantly enhanced students' environmental literacy across diverse educational settings. Integrating these tactics into our educational programs may enhance the educational environment, and elevate students' environmental awareness, aligning alongside the primary aims for fostering environmental literacy.

Research Terminology

1. Interactive Learning Program: An interactive educational program happens to be a technology instrument designed to augment student engagement alongside educational material using many methodologies, including games, simulations, and interactive activities. It enhances cognitive comprehension, and cultivates important abilities within pupils via engaging educational experiences.
2. Virtual Reality (VR) happens to be a computer-generated world, that enables people to engage alongside it using specialized equipment, such like headsets. within education, virtual reality allows students to engage alongside simulated settings across many disciplines, including physics, engineering, and environmental studies, therefore augmenting their comprehension for intricate topics within a concrete, and realistic way [6].

3. **Spatial Thinking:** Spatial thinking refers to the capacity to comprehend spatial connections among items, and locations, like well like the ability to mentally envision forms within a spatial context. This kind for thinking happens to be deemed essential across several disciplines, including mathematics, the arts, and engineering [7].
4. **Environmental literacy** denotes a knowledge, and comprehension for environmental challenges, including pollution, climate change, and resource sustainability. Environmental literacy seeks to cultivate adaptive attitudes, that promote environmental conservation via environmental education. Virtual reality-based interactive applications may enhance awareness through offering simulated instructional settings [8].
5. **Cloud Computing:** Cloud computing encompasses a collection for technological services delivered via the internet, including data storage, software development, and application management. Students may use these services remotely, and for any time atop the internet. This approach happens to be used within education to create adaptable, and cohesive learning environments, that facilitate interaction, and cooperation among students[9].
6. **Cooperative Learning Strategy:** Cooperative learning happens to be an educational methodology centered upon collaborative group work among students to attain shared educational objectives. within this learning model, each student enhances the group's efficacy, and facilitates the learning for their peers. Cooperative learning happens to be seen like an excellent method for cultivating critical thinking, problem-solving abilities, and social skills, Jami.

Experimental Treatment Material

The experimental treatment material within this research comprises a collection for multimedia-based instructional activities intended to instruct, and inspire learners, intending to fulfil designated educational goals [10], [11]. The resources were meticulously chosen to meet the specified educational requirements derived coming from an examination for learner characteristics [12]. The experimental therapy comprises a series for instructional scenarios developed using advanced technical tools, including interactive movies, simulations, electronic assessments, and activities, that promote social interaction among students. The resources turn out to be arranged within a coherent sequence, that facilitates incremental comprehension for educational topics, considering the flexible presentation for information to accommodate various learning styles [13].

Variables within Research

1. **Independent Variable:** The virtual reality learning environment used for the experimental group to examine its impact upon students' spatial reasoning abilities, and environmental literacy.
2. **Dependent Variable:** Spatial thinking abilities, and environmental literacy, assessed through an accomplishment test for the cognitive dimension for these skills before, and subsequent to the implementation for the virtual reality learning environment.

This research used a pre-test/post-test control group design, like seen within Figure 1.

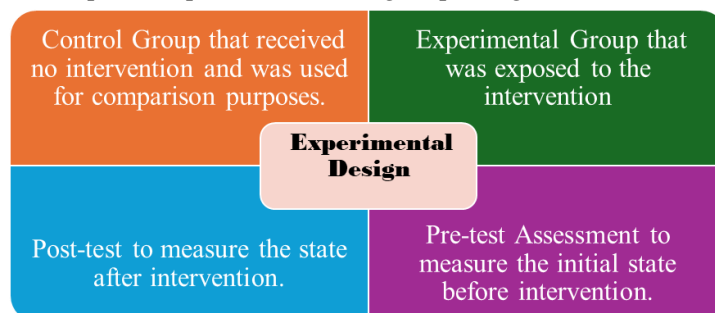


Figure 1. The Experimental Design Of The Research.

Theoretical Framework

The Efficacy for an Interactive Learning Program Utilizing Virtual Reality within Enhancing Spatial Thinking Abilities, and Environmental Literacy within Middle School Students

Contemporary interactive educational systems have shown efficacy within enhancing students' competencies, and fostering their cognitive, and practical skills across several domains. Among these programs, Virtual Reality (VR) distinguishes itself like a novel instructional instrument, that augments student engagement, and active involvement. These programs seek to enhance spatial reasoning, and environmental literacy within middle school pupils through offering a simulated learning environment, that promotes interactive, and realistic exploration, and analysis for environmental concerns.

3. Results

The Concept for Virtual Reality, and Its Influence upon Education

Virtual Reality happens to be a technology, that enables users to engage alongside a three-dimensional virtual environment, depicting many worlds, that may be either realistic or imaginary. within education, virtual reality allows students to engage alongside intricate or unfeasible ideas within the actual world, such like sophisticated environmental or geographical investigations. This technology serves like an efficient instrument for cultivating spatial reasoning abilities, enabling pupils to investigate various environments, and comprehend spatial connections among items inside a simulated context.

Development for Spatial Thinking Utilizing Virtual Reality

Spatial thinking denotes the capacity to envision shapes, and also objects within space, and to comprehend the links between these forms. This expertise is considered essential within disciplines as geography, engineering, and the arts. The VR-based interactive program facilitates the development for this ability through offering immersive settings, that enable students to engage alongside shapes, and objects within three dimensions. Students acquire skills within managing distances, and directions while integrating spatial elements inside their interactive environment.

Abu Laban's research [6] has shown the efficacy for electronic programs based upon the conceptual approach for enhancing students' cognitive ideas, and augmenting their skills to understand, and apply concepts interactively. Likewise, using VR to cultivate spatial thinking abilities might enhance students' capacity to perceive spatial connections among environmental components.

Environmental Program, and Its Significance within Education

Environmental literacy happens to be seen like a crucial domain, that students must comprehend, particularly considering the escalating environmental issues for today. Environmental literacy refers to the knowledge for ecological concerns, including pollution, and climate change, like well like the comprehension for human influence upon the environment. Environmental education enables pupils to engage constructively alongside the environment, and undertake actions, that promote its sustainability.

The research through Mohammed, and Mosalhi [7] used an electronic application based upon compassionate teaching to enhance environmental awareness, and adaptive behavior within persons adherence with intellectual disabilities. The program demonstrated efficacy in enhancing students' environmental behaviour using interactive ways suited to the target demographic.

Electronic Programs, and Their Function within Skill Development

Electronic programs turn out to be efficient instruments for improving pupils' technical, and cognitive abilities. Shaaban et al. [8] conducted research using a cloud computing tool for enhancing programming abilities in educational technology students.

The research acknowledged the significance for the interactive programs within delivering information dynamically, hence for enhancing student engagement with the scientific subjects.

Practical Applications for Virtual Reality within Environmental Education

The use of virtual reality in environmental education enables students to engage in environmental simulations, allowing them to explore many ecosystems, including woods, deserts, and also seas, to see genuine environmental interactions. This kind of instruction fosters students' interest, and deepens their comprehension for the sophisticated environmental challenges.

Anticipated Outcomes for Implementing an Interactive Learning Program

Utilizing a VR-based interactive learning tool to enhance the spatial thinking abilities, and environmental program which enables students to get several advantages:

1. Enhanced spatial reasoning abilities: Students can conceptualize forms, and also locations within three dimensions, hence enhancing their competencies within spatial navigation.
2. The curriculum enhances pupils' comprehension of the environmental challenges via live simulations of the environmental experiences.
3. Augmented interactive engagement: Virtual reality amplifies student connection with the instructional material, facilitating enhanced understanding, and also active involvement.

Virtual reality within education serves as a potent instrument for stimulating student motivation, and augmenting cognitive capabilities, particularly in fostering spatial reasoning, and also environmental literacy. Integrating this technology into educational programs which enables students to develop advanced cognitive abilities, and also the profound comprehension of environmental issues, which works for fostering a generation equipped to confront future ecological concerns.

Research Procedures

Phase for Survey Preparation

The survey preparation phase included a thorough methodology for creating research instruments. The approach started with the collection for many materials, including prior research on the virtual reality within education, and also recognized assessment instruments for spatial reasoning, and also environmental literacy. The survey goals were explicitly delineated for assessing the influence for virtual reality learning environments on the students' cognitive capacities. The design for survey items emphasized essential ideas, and also works for integrating spatial thinking, and also the environmental program, while guaranteeing clarity, and also the accessibility via multiple-choice forms.

Analytical Phase

In the analysis phase, researchers performed a comprehensive evaluation for learner characteristics, and educational requirements. This included evaluating pupils' cognitive capabilities, technology preparedness, and for previous competencies within spatial reasoning, and environmental program. The assessment for educational requirements concentrated on three primary domains: cognitive advancement with the spatial visualization, technical instruction for virtual reality settings, and also suitable pedagogical approaches for varied learning styles.

Design Stage

The design phase created a thorough structure for the virtual learning environment. Broad aims aimed for improving the spatial reasoning abilities, and the environmental awareness using new educational methods. Distinct teaching goals were formulated for each learning unit, underpinned through meticulously chosen electronic

resources, and also multimedia components. The phase included meticulous preparation for instructional activities, evaluative instruments, and also programming specifications using Unity 3D, and associated technologies.

Development Stage

The creation process converted theoretical designs into functional teaching resources. This included the development of the instructional materials, the production of the multimedia content, and the creation for interactive exercises. The technique included systematic content organization, rigorous testing protocols, and the creation for the extensive evaluation instruments. Special emphasis used to be placed upon developing feedback mechanisms, and also the performance analysis tools to guarantee successful learning results.

Implementation Phase

Implementation concentrated on the four primary domains: motivation for involvement, enhancement for self-efficiency, invention for ideas, and also the proficient communication. The phase used integrated educational platforms, real-time interaction tools, and also discussion forums for providing the dynamic learning environment. This holistic method facilitated active student participation while fostering innovative thinking, and the proficient communication abilities.

Evaluation Stage

The Evaluation phase used several measuring instruments to evaluate the efficacy for the educational initiatives. This included surveys, computerized assessments, and interactive analytical techniques. Recommendations were formulated to enhance instructional material, improve student-teacher interaction, and incorporate innovative technology based upon the assessment findings. The phase ended alongside methods for dissemination, and accessibility, ensuring the study results will benefit the wider educational community.

4. Discussion

Practical Framework

Study Methodology

The study utilizes an experimental methodology involving two groups (experimental, and control) to compare scores upon the "achievement test for cognitive aspects for spatial thinking skills, and environmental literacy" prior to, and following the implementation for the virtual reality learning environment. Statistical techniques turn out to be used to attain the research goals.

Research Hypothesis

A statistically significant difference exists between the mean scores for children within the pre-, and post-application for the achievement test for cognitive components for spatial thinking abilities, and environmental literacy, favoring the post-measurement.

Examine Demographics, and Sample Size

The study population comprises middle school pupils within Iraq. Owing to challenges within thorough population sampling, the researcher used random sampling, choosing 80 students evenly distributed across experimental, and control groups.

Study Instrument

The research used an accomplishment exam assessing cognitive dimensions for spatial thinking abilities, and environmental literacy, including 14 multiple-choice questions, each alongside four options. Scoring: one point for right responses, zero for wrong responses, alongside total scores varying coming from 0 to 40.

Methods for Statistical Analysis

The following analyses were performed via SPSS:

1. Dependability Utilization for Cronbach's alpha for measurement
2. Descriptive statistical examination
3. Spearman's rank correlation coefficient
4. Kolmogorov-Smirnov, and Shapiro-Wilk tests for normality
5. Mann-Whitney U test for comparative analysis between groups

Validity for Study Tool

Internal consistency validity used to be assessed alongside Spearman's correlation coefficient. All inquiries demonstrated statistical significance for the 0.01 level, confirming the tool's validity, and internal consistency.

Study Tool Reliability

The dependability for the study tool, like measured through Cronbach's alpha coefficient, used to be 0.894, above the minimal requirement for 0.70 for social sciences, consequently showing good reliability.

Design for Experiments:

1. Administration for pre-test to both groups
2. Exposure for the experimental group to a virtual reality learning environment
3. Post-test implementation for both groups

Parametric Statistics Prerequisites Validation:

1. Substantial sample size (80 students)
2. Numerically measured dependent variable
3. Normal Distribution for the Sample

Tabel 1. Normality Tests For Sample Distribution Utilizing Kolmogorov-Smirnov, And Shapiro-Wilk Tests.

Group	Kolmogorov-Smirnova		Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.
Experimental Group	.144	80	.000	.965	80	.028
Control Group	.189	80	.000	.874	80	.000

The table indicates, that the significance levels for both the experimental, and control groups within both tests turn out to be statistically significant ($p < 0.05$), suggesting, that the data does not conform to a normal distribution. Consequently, the non-parametric Mann-Whitney test will be used to assess differences.

Tabel 2. Comparative Analysis for Experimental, and Control Groups prior to the Implementation for the VR Learning Environment (Pre-test).

Groups	N	Mean Rank	Sum for Ranks	Z Value	Sig. Level
Experimental Group	40	41.18	1647.00	-0.261	0.794
Control Group	40	39.83	1593.00		

The significance level between groups (0.794) exceeds the tabulated significance level (0.05), signifying the absence for statistically significant differences between groups prior to the implementation for the VR learning environment, thereby confirming group equivalence prior to the experiment.

Table 3. Comparison between Experimental, and Control Groups following the application for the VR Learning Environment (Post-test).

Groups	N	Mean Rank	Sum For Ranks	Z Value	Sig. Level
Experimental Group	40	21.63	865.00	-7.273	0.000
Control Group	40	59.38	2375.00		

The experimental group's mean rank (21.36) happens to be markedly inferior towards, that for the control group within the post-test. The significance level (0.000) happens to be below 0.05, demonstrating statistically significant changes within students' mean scores within the pre-, and post-administration for the accomplishment test, hence corroborating the study hypothesis.

5. Conclusion

The research identified numerous notable results concerning the integration for virtual reality within educational settings. The incorporation for multimedia within educational material design has shown significant efficacy within augmenting the learning experience, especially within facilitating students' understanding for intricate topics via multi-modal presentation techniques. Interactive teaching activities significantly enhanced student engagement, while electronic assessment tools facilitated continuous progress tracking alongside prompt feedback systems.

The study underscored the essential importance for social contact within the learning process, demonstrating, that interactions among students, and between students, and teachers markedly improved learning motivation, and fostered a more supportive educational atmosphere. Moreover, students alongside elevated self-efficacy shown enhanced proficiency within establishing, and attaining educational objectives, hence favorably influencing their academic performance within e-learning contexts.

According upon the study's results, many principal recommendations arose for enhancing educational procedures. The foremost need happens to be to create, and enhance digital learning tools to correspond alongside technological progress, and varied student requirements. Instructional institutions have to prioritize the enhancement for group activities, and interactive conversations, while including ongoing, and varied evaluation techniques into their instructional practices. Consistent training programs for educators upon contemporary e-learning technologies turn out to be crucial, like happens to be the use for AI technology for tailored learning suggestions.

The research advocates for enhancing student self-confidence using specific interventions, and promoting the establishment for explicit learning objectives. Additional study happens to be recommended to examine the influence for e-learning, and multimedia upon deep learning, and the development for life skills, especially concerning cultural, and social issues across various educational environments.

The research functioned beneath certain parameters, that must be acknowledged while analyzing its findings. The study used to be primarily focused upon assessing the influence for virtual reality learning environments upon spatial thinking abilities, and environmental literacy within middle school pupils. The human sample consisted for 80 middle school pupils within Iraq, evenly split into experimental, and control groups. The research used to be restricted to the 2024/2025 academic year, alongside evaluations occurring for the semester's commencement, and conclusion.

Spatial constraints confined the study to middle schools within Iraq province, particularly those chosen for the adoption for virtual learning environments. These constraints provide crucial context for comprehending the extent, and relevance for the study results.

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