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UNLOCKING MINDS IN 3D: HOW VIRTUAL REALITY TRANSFORMS LEARNING FOR ELEMENTARY SCHOOL STUDENTS

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ABSTRACT

This study investigates the impact of VR-based instruction on learning outcomes in Islamabad, Pakistan's elementary education sector. Using a quasi-experimental design, data was collected from 500 students across ten elementary schools, including demographic information, standardized tests, surveys, and performance tasks. Statistical analyses, including descriptive statistics, chi-square tests, t-tests, ANOVA, and regression coefficient analysis, were conducted to assess VR-based instruction effectiveness. Findings suggest VR engages younger students effectively, especially those with lower academic performance and limited technology exposure. Significant effects were observed on spatial learning, cognitive development, and engagement. Despite slightly lower mean scores, VR instruction offers significant benefits, underscoring its potential for integration into elementary education. The study concludes that VR technology has transformative potential, enhancing spatial learning, cognitive development, and engagement. Policy implications include investing in VR infrastructure and teacher training to foster inclusive and innovative educational practices. Future research should address limitations and explore long-term effects to maximize VR-based instruction effectiveness and ensure equitable educational opportunities.

Keywords: *VR-Based Instruction, Elementary Schools, Students, Significant Effects, Spatial Learning, Cognitive Development, Integration.*

INTRODUCTION

Virtual reality (VR) technology has emerged as a groundbreaking tool with the potential to revolutionize education, particularly in enhancing spatial learning and cognitive development among elementary school students (Zhang et al., 2022). In an increasingly digital world, where spatial awareness and critical thinking are crucial for success, the integration of VR into educational settings holds significant promise (Schneider, 2021). This transformative technology offers immersive experiences that transcend traditional classroom boundaries, fostering engagement, motivation, and personalized learning tailored to individual student needs.

Across the globe, educators recognize the importance of equipping students with the skills necessary to navigate complex spatial environments and solve intricate problems. VR technology provides a unique platform to address these educational goals by offering interactive simulations that enhance spatial awareness and three-dimensional comprehension (Molina-Carmona et al., 2018). Moreover, it fosters cognitive development through immersive experiences that stimulate problem-solving skills, critical thinking, and memory retention. By leveraging VR, educators can create dynamic learning environments that captivate students' interest and inspire a deeper understanding of abstract concepts.

In Pakistan, where access to quality education remains a challenge for many, the potential impact of VR technology on spatial learning and cognitive development is particularly significant. With a growing emphasis on 21st-century skills and STEM (Science, Technology, Engineering, and Mathematics) education, VR presents an opportunity to bridge educational gaps and empower students with essential competencies for future success (Penprase, 2020). By integrating VR into elementary school curricula, Pakistan can enhance the educational experience, promote active learning, and foster a culture of innovation and inquiry among its youth.

In the capital city of Islamabad, where educational reforms are underway to modernize teaching methodologies and improve learning outcomes, the adoption of VR technology holds immense promise. By embracing VR-based learning initiatives, schools in Islamabad can transcend traditional pedagogical approaches and offer students immersive experiences that enrich spatial learning and cognitive development. Moreover, integrating VR into the curriculum aligns with national educational goals to promote innovation, creativity, and critical thinking skills among students, thereby preparing them to thrive in an increasingly competitive global landscape.

In conclusion, the impact of VR technology on spatial learning and cognitive development among elementary school students is profound, both globally and within the context of Pakistan, particularly in Islamabad. By harnessing the potential of VR, educators can create engaging, personalized learning experiences that empower students to explore, collaborate, and excel in an ever-evolving educational landscape. Through strategic implementation and ongoing support, VR technology has the potential to revolutionize education, equipping the next generation with the skills needed to navigate and succeed in an increasingly complex world.

Literature Review

Research indicates that VR technology enhances spatial learning by providing immersive experiences that engage multiple senses and facilitate the understanding of three-dimensional concepts (Makransky & Petersen, 2021). Studies have demonstrated that students exposed to VR simulations show significant improvements in spatial awareness and navigation skills (Papanastasiou et al., 2019). Additionally, VR-based interventions have been shown to enhance spatial reasoning abilities, leading to better performance in tasks requiring mental rotation and visualization (Zhou et al., 2022). In Islamabad, where traditional teaching methods may not adequately address spatial learning needs, integrating VR technology into classrooms can be transformative (Rahman-Shams, 2019). With empirical evidence supporting the efficacy of VR in enhancing spatial understanding, educators in Islamabad can utilize this technology to bridge learning gaps and provide students with hands-on experiences that foster a deeper comprehension of abstract spatial concepts.

Numerous studies have highlighted the cognitive benefits of VR technology in education. Interactive VR experiences promote problem-solving skills by engaging students in complex scenarios that require critical thinking and decision-making (Asad et al., 2021). Moreover, the multisensory nature of VR enhances memory retention and recall, leading to better learning outcomes (Hamilton et al., 2021). VR-based interventions have also been associated with improvements in executive functions such as attention and working memory (Parong & Mayer, 2021). In Islamabad, where cognitive development is a key focus of educational reforms, incorporating VR technology into the curriculum can have profound implications. By leveraging empirical evidence supporting the cognitive benefits of VR, educators in Islamabad can design immersive learning experiences that nurture critical thinking and memory skills among students, thereby fostering intellectual growth and academic success (Riaz et al., 2021).

Empirical studies indicate that VR technology enhances student engagement and motivation by offering immersive, interactive learning experiences (Liu et al., 2020). The sense of presence and agency in VR environments captivates learners' attention and encourages active participation (Parong & Mayer, 2018). Additionally, the novelty of VR technology generates excitement and curiosity, driving intrinsic motivation to explore and learn (W. Huang et al., 2021). In Islamabad, where student engagement is a concern in traditional classrooms, integrating VR technology can reinvigorate learning experiences. Drawing on global research highlighting the motivational benefits of VR, educators in Islamabad can leverage this technology to spark curiosity and enthusiasm for learning among students, thereby fostering a positive learning environment conducive to academic success.

Empirical evidence suggests that VR technology facilitates individualized learning experiences by accommodating diverse learning styles and preferences (Gregory et al., 2016). VR environments can be customized to suit the pace and preferences of each student, providing personalized feedback and adaptive learning pathways (Xie et al., 2019). This tailored approach enhances student autonomy and self-efficacy, leading to improved learning outcomes (Premlatha & Geetha, 2015). In Islamabad, where student diversity and varying learning needs pose challenges to traditional teaching methods, VR technology offers a solution. By drawing on global research highlighting the effectiveness of individualized learning in VR environments, educators in Islamabad can leverage this technology to provide tailored instruction that meets the needs of diverse learners, thereby promoting inclusive education and equitable access to learning opportunities.

Studies have demonstrated the efficacy of VR technology in promoting collaboration and social interaction among students (Çoban & GOKSU, 2022). Virtual environments provide opportunities for synchronous communication and teamwork, fostering the development of interpersonal skills and cooperative learning (Vlachopoulos & Makri, 2019). Collaborative VR activities have been shown to enhance student engagement and deepen understanding through peer interaction and knowledge sharing (Chen et al., 2018). In Islamabad, where fostering collaboration and social interaction is essential for holistic student development, VR technology can play a transformative role. Building on global research highlighting the collaborative benefits of VR, educators in Islamabad can integrate collaborative VR activities into the curriculum to promote teamwork, communication skills, and peer learning, thereby preparing students for success in an interconnected world (Madden et al., 2020).

Empirical studies have identified potential ethical and safety considerations associated with VR technology in education (Chittaro et al., 2017). Prolonged exposure to VR may lead to discomfort or motion sickness in some users, highlighting the need for responsible usage guidelines (Conner et al., 2022). Additionally, ensuring the ethical use of VR content is essential to safeguarding student well-being and privacy (Brunzini et al., 2023). In Islamabad, where ensuring the ethical and safe use of technology is paramount, addressing these considerations is crucial for the successful implementation of VR in education. By drawing on global research on ethical and safety concerns related to VR, educators in Islamabad can develop policies and guidelines to promote responsible usage and protect student welfare, thereby fostering a supportive and secure learning environment.

Research emphasizes the importance of teacher training and support in effectively integrating VR technology into the curriculum (Huang et al., 2023). Educators require professional development opportunities to familiarize themselves with VR tools and instructional strategies (Chen et al., 2021). Ongoing support and resources are essential for empowering teachers to leverage VR technology to its full potential (Burden et al., 2019). In Islamabad, where teacher capacity-building is essential for successful educational reforms, providing training and support for VR integration is critical. Drawing on global research highlighting the significance of teacher professional development in VR implementation, policymakers in Islamabad can invest in training programs and resources to equip educators with the skills and knowledge needed to effectively leverage VR technology in the classroom, thereby enhancing teaching quality and student learning outcomes.

Establishing valid metrics for assessing the effectiveness of VR-based learning interventions is essential for evidence-based practice (Appleby et al., 2019). Empirical studies employ a variety of assessment methods, including pre-posttests, observation, and qualitative feedback, to evaluate the impact of VR on learning outcomes (Farič et al., 2021). Longitudinal studies are needed to assess both short-term and long-term impacts on spatial learning and cognitive development (Makransky & Mayer, 2022). In Islamabad, where evidence-based decision-making is crucial for educational reform, developing robust assessment frameworks for VR-based learning is imperative. Drawing on global research on assessment and evaluation in VR education, policymakers in Islamabad can collaborate with researchers to design comprehensive evaluation tools and methodologies that capture the multifaceted impacts of VR on student learning, thereby informing policy decisions and driving continuous improvement in educational practices.

Addressing disparities in access to VR technology is essential for ensuring equitable educational opportunities (AlGerafi et al., 2023). Empirical studies highlight the importance of providing infrastructure and resources to support VR implementation in schools serving underserved communities (Pregowska et al., 2021). Strategies such as mobile VR labs and community partnerships can expand access to VR experiences for all students (Towey et al., 2018). In Islamabad, where addressing educational inequalities is a priority, ensuring equitable access to VR technology is essential. Drawing on global research on access and equity in VR education, policymakers in Islamabad can implement strategies to provide infrastructure and resources to schools in marginalized areas, thereby ensuring that all students have the opportunity to benefit from immersive learning experiences, regardless of socioeconomic status or geographic location.

Aligning VR experiences with educational standards and learning objectives is essential for maximizing learning outcomes (Wu et al., 2023). Empirical studies demonstrate the effectiveness of integrating VR technology as a supplementary tool to enhance existing curriculum materials (Y. Huang et al., 2021). By embedding VR activities within curricular frameworks, educators can ensure that learning experiences are relevant, coherent, and aligned with instructional goals (Kier & Johnson, 2022). In Islamabad, where curriculum alignment is critical for educational quality and coherence, integrating VR technology into existing standards can enrich teaching and learning practices. Building on global research on curriculum integration in VR education, policymakers in Islamabad can collaborate with curriculum developers and educators to identify opportunities for embedding VR activities that enhance student engagement and achievement, thereby fostering a seamless integration of technology and pedagogy in the classroom.

Statement of the Problem

Despite the growing recognition of the potential benefits of virtual reality (VR) technology in enhancing spatial learning and cognitive development globally, its integration into educational settings in Islamabad, Pakistan remains limited. The lack of comprehensive research and empirical evidence on the impact of VR technology on elementary school students' spatial learning and cognitive development in Islamabad presents a significant gap in the literature. Furthermore, existing studies often focus on high-income countries, neglecting the unique context and challenges faced by schools in Islamabad. Therefore, there is a pressing need to investigate the effectiveness of VR-based interventions in elementary schools in Islamabad and explore how they can address the educational needs of students in this context.

The aim of this study is to examine the impact of virtual reality (VR) technology on spatial learning and cognitive development among elementary school students in Islamabad, Pakistan. Specifically, the study aims to assess the effectiveness of VR-based interventions in enhancing spatial awareness, navigation skills, problem-solving abilities, and critical thinking skills among students. Additionally, the study seeks to explore the perceptions of teachers and students regarding the integration of VR technology into the curriculum and identify potential challenges and opportunities associated with its implementation.

This study is justified by the urgent need to enhance educational practices in Islamabad, Pakistan, and address the persistent challenges faced by elementary schools in promoting spatial learning and cognitive development. By investigating the impact of VR technology on student outcomes and exploring its potential as an educational tool, this study seeks to inform evidence-based decision-making and educational policy formulation in Islamabad. Furthermore, by filling the existing gap in the literature on VR technology in the context of Islamabad, this study contributes to the advancement of knowledge and understanding of innovative teaching methodologies tailored to local educational needs.

The gap in the literature lies in the lack of comprehensive research on the effectiveness of virtual reality (VR) technology in elementary schools in Islamabad, Pakistan. While numerous studies have examined the impact of VR on spatial learning and cognitive development globally, few have focused specifically on low- and middle-income countries such as Pakistan, where access to technology and educational resources may be limited. This study fills this gap by conducting empirical research in elementary schools in Islamabad, thereby providing valuable insights into the potential benefits and challenges of integrating VR technology into the curriculum in this context.

The study is important as it addresses a critical gap in the literature on the use of VR technology in education in Islamabad, Pakistan. Furthermore, the study contributes to the novelty of educational research in Islamabad by exploring innovative approaches to teaching and learning that leverage emerging technologies such as VR, thereby paving the way for future research and educational practices in the region.

Materials and Methods

Research Design

A quasi-experimental design employed by Campbell and Stanley (2015) in their book titled "Experimental and Quasi-experimental Designs for Research" was utilized to investigate the impact of VR-based interventions on spatial awareness, navigation skills, problem-solving abilities, and critical thinking skills among elementary school students in Islamabad, Pakistan. The researchers created two groups: a treatment group receiving VR-based instruction and a control group receiving traditional instruction. The novelty of this methodology lies in its comprehensive approach to assessing the impact of VR technology on cognitive development within a specific educational context. This is achieved through rigorous sampling techniques, utilization of a variety of assessment tools, and ensuring the reliability and validity of data through statistical analysis and instrument validation.

Study Setting and Universe

The study was conducted in Islamabad, Pakistan, involving ten top-ranked elementary schools, namely Roots Millennium School, Headstart School, Beaconhouse School System, Supernova School, Roots International Schools, The City School, OPF School, Foundation Public School, Global System of Integrated Studies, and International Grammar School and College. The target population for this study comprised elementary school students in Islamabad, Pakistan.

Participants were selected to represent diverse demographics such as age, gender, academic performance, and prior exposure to technology. Age categories were defined as participants aged 6-8 years, participants aged 9-11 years, and participants aged 12-14 years for both the treatment group (VR-based instruction) and the control group (traditional instruction). These age categories ensured representation across different developmental stages, enabling an analysis of how VR-based instruction impacts spatial learning and cognitive development at various age levels. Gender categories for both groups were identified as male and female. This categorization enabled an examination of potential gender differences in response to VR-based instruction, contributing to a comprehensive understanding of its effectiveness. Academic performance categories for both the treatment group (VR-based instruction) and the control group (traditional instruction) were set as follows:

Low: Participants with a Grade Point Average (GPA) below 3.0

Moderate: Participants with a GPA between 3.0 and 4.0

High: Participants with a GPA of 4.0 or higher

This categorization allowed for an exploration of how academic performance levels influence the effectiveness of VR-based instruction on spatial learning and cognitive development.

Prior exposure to technology categories for both groups were designed as follows:

Low: Participants with less than 2 hours of technology exposure per day

Moderate: Participants with 2-4 hours of technology exposure per day
High: Participants with more than 4 hours of technology exposure per day
This categorization facilitated an investigation into the role of prior exposure to technology in shaping the outcomes of VR-based instruction on spatial learning and cognitive development.

Sampling and Sample Size
Bi-sampling techniques, including stratified random sampling and purposive sampling, were utilized. Participants were chosen through stratified random sampling, ensuring representation from diverse demographics such as age, gender, and academic performance, while purposive sampling techniques were employed to select samples from each school. A total of 500 samples, with 50 from each school, were selected. Among these, 250 received VR-based instruction while the remaining 250 comprised the control group receiving traditional instruction, as required by the quasi-experimental design. This sampling technique was chosen to improve the generalizability of the findings.

Data Collection Method
Quantitative data were collected through standardized tests, surveys, and performance tasks. Demographic information was gathered on age, gender, academic performance, and prior exposure to technology. Pre-and post-intervention assessments were administered to both the treatment and control groups. These tools were designed to evaluate specific cognitive abilities and spatial skills relevant to the study's objectives. Questionnaires included Likert scale items to gauge participants' perceptions of VR technology and its impact on learning outcomes. Rigorous measures were undertaken to ensure the reliability and validity of the instruments through pilot testing, expert validation, and statistical analysis using SPSS software (Field, 2013). Data collection procedures entailed administering pre-intervention assessments to both the treatment group (receiving VR-based instruction) and the control group (receiving traditional instruction). Following the intervention, post-intervention assessments were conducted to measure changes in learning outcomes. Demographic variables such as age, gender, academic performance, and prior exposure to technology were considered during data analysis to control potential confounding variables.

Ethical Considerations
In the study "Unlocking Minds in 3D: How Virtual Reality Transforms Learning for Elementary School Students," rigorous ethical considerations were addressed to ensure participant protection and research integrity. Confidentiality was maintained by anonymizing data and securely storing sensitive information. Informed consent was obtained from parents or guardians due to the participants being under 18, ensuring they were fully informed about the study’s purpose, procedures, risks, and benefits. Additionally, child participants were provided with age-appropriate explanations to obtain their assent, respecting their autonomy. Data collection was conducted in the presence of teachers or principals to provide oversight and ensure the research activities were appropriately managed, though care was taken to minimize undue influence on the participants. These measures ensured the study was ethically sound, protecting participants' rights, safety, and well-being.

Data Analysis
Data were analyzed using SPSS software, employing measures of central tendency to describe the distribution of data within both groups. Additionally, chi-square tests were conducted to examine the association between independent and dependent variables in the context of treatment and control groups. Statistical techniques such as t-tests, ANOVA, and regression analysis were utilized to compare outcomes between the treatment and control groups, aiming to determine the effectiveness of VR technology in enhancing student learning outcomes.

Model of the Study
The following model was designed to specify the relationships between the dependent variable (learning outcomes) and the independent variables (type of instruction, age, gender, GPA, and prior exposure to technology, etc.). Given this context, descriptive statistics, chi-square test, t-test, ANOVA, and multiple regression model are appropriate to capture these relationships.

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$$Y=\beta 0+\beta 1X1+\beta 2X2+\beta 3X3+\beta 4X4+\beta 5X5+\epsilon$$

Where,
Y: Learning Outcome
β0: Intercept term
β1: Coefficient for VR-Based Instruction
X1: VR-Based Instruction (1 if VR-based instruction, 0 if traditional instruction)
β2: Coefficient for Age
X2: Age
β3: Coefficient for Gender
X3: Gender
β4: Coefficient for Academic Performance
X4: Academic Performance
β5: Coefficient for Prior Exposure to Technology
X5: Prior Exposure to Technology
ϵ: Error term

This model incorporates various aspects:
Descriptive Statistics: Age, Gender, Academic Performance, and Prior Exposure to Technology are included as explanatory variables (X2, X3, X4, X5) based on their descriptive statistics findings.

Chi-Square Test: The overall effect of VR-Based Instruction is captured by X1, indicating whether the instruction was VR-based or traditional.

T-Test, ANOVA, and Regression Coefficient: The coefficient β1 represents the impact of VR-Based Instruction on learning outcomes, capturing the findings from the t-test, ANOVA, and regression analysis.

Conceptual Framework

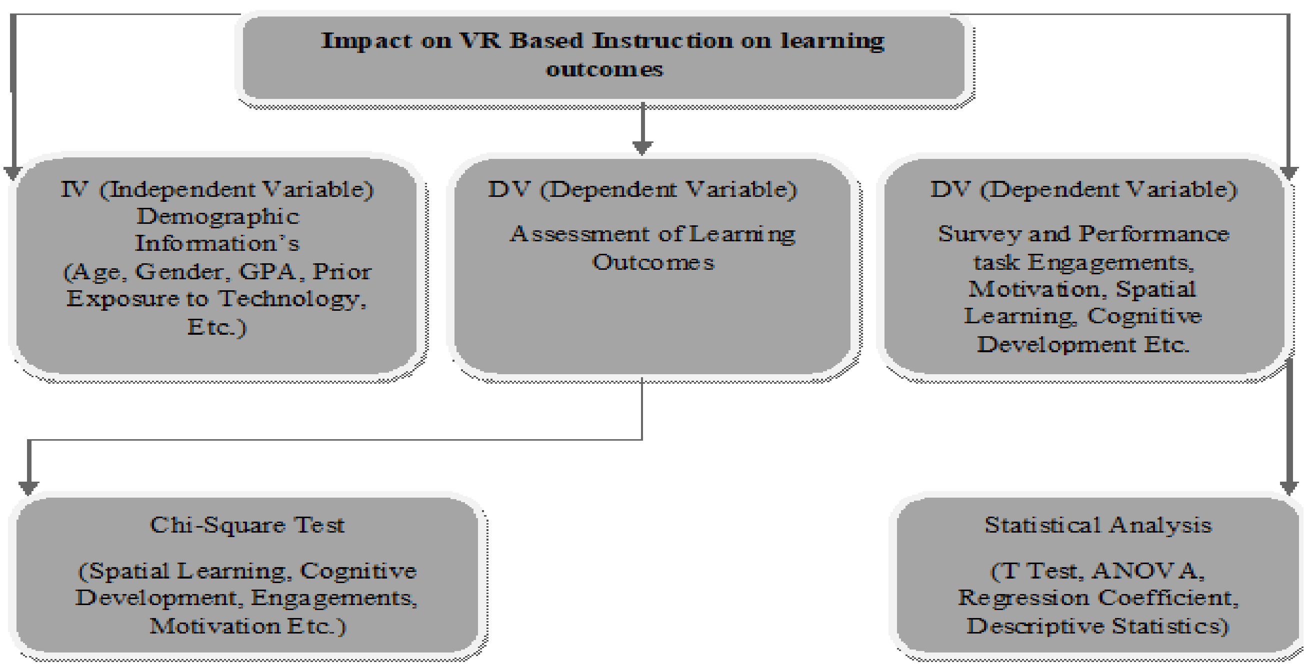

Figure-1

Limitations and their Mitigations

Limitations of the study, including logistical challenges and biases, were addressed through rigorous sampling techniques, transparent data collection procedures, and statistical analysis to control for potential confounding variables. Efforts were made to mitigate biases and enhance the validity and reliability of the study findings.

Results

Table-1: Demographic Variables in Relations with Descriptive Statistics

Treatment Group (VR Based Instruction)							Control Group (Traditional Instruction)						
Age	F	Mean	Median	Mode	Variance	SD	Age	F	Mean	Median	Mode	Variance	SD
6-8	55						6-8	55					
9-11	64	1.152	2.00	3	0.025	0.158	9-11	64	2.134	2.56	3	0.452	0.672
12-14	131						12-14	131					
Total	250						Total	250					
Gender	F						Gender	F					
Male	125	1.05	1.00	2	0.005	0.070	Male	125	1.55	1.01	2	0.578	0.760
Female	125						Female	125					
Total	250						Total	250					
AP	F						AP	F					
GPA<3.0	16						GPA<3.0	98					
GPA=3.5	68	1.03	3.00	3	0.007	0.083	GPA=3.5	102	2.05	2.00	2	0.876	0.936
GPA=4	166						GPA=4	50					
Total	250						Total	250					
PET	F						PET	F					
2<Hours	53						2<Hours	103					
3=Hours	97	1.23	3.00	4	0.006	0.078	3=Hours	102	2.87	2.00	1	0.987	0.993
4=Hours	100						4=Hours	45					
Total	250						Total	250					

Source: Authors' calculations

Table 1 displays the results of demographic variables along with descriptive statistics for both the treatment group (VR-Based Instruction) and the control group (Traditional Instruction) as outlined in the study. The details of the results are provided below:

Age: In the treatment group, the mean age of participants is approximately 1.15 years, with a median of 2. The mode is 3, indicating that a significant portion of participants falls within this age range. The variance is relatively low at 0.025, suggesting that ages are clustered closely around the mean. The standard deviation is also low, indicating consistency in age distribution. In contrast, the control group has a higher mean age of around 2.13 years, with a median of 2.56. Like the treatment group, the mode is 3, indicating a concentration of participants in this age range. However, the variance and standard deviation are higher compared to the treatment group, suggesting greater variability in age among participants.

The numerical values of mean, median, mode, variance, and standard deviation of age in the Treatment Group are significantly lower than in the Control Group. This suggests that the treatment group consists of younger students, potentially indicating greater engagement with VR-based instruction.

Gender: Within the treatment group, the mean age for females is approximately 1.05 years, with a median of 1. The mode is 2, indicating a balanced distribution between males and females. The variance and standard deviation are relatively low, indicating consistency in age distribution among genders. Conversely, in the control group, the mean age for females is higher at approximately 1.55 years, with a median of 1.01. Similar to the treatment group, the mode is 2, suggesting a balanced gender distribution. However, the variance and standard deviation are higher compared to the treatment group, indicating greater variability in age distribution among genders.

Both groups have similar gender distributions, but the mean, median, mode, variance, and standard deviation in the Treatment Group are lower than in the Control Group. This implies that VR-based instruction may be more appealing to younger students, regardless of gender.

Academic Performance: In the treatment group, the mean GPA for students with GPAs below 3.0 is approximately 1.03. The median GPA is 3.00, with a mode of 3. The variance and standard deviation are relatively low, indicating consistency in academic performance among students with lower GPAs. Conversely, in the control group, the mean GPA for students with GPAs below 3.0 is higher at around 2.05. The median GPA is 2.00, with a mode of 2. The

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variance and standard deviation are higher compared to the treatment group, indicating greater variability in academic performance among students with lower GPAs.

The Treatment Group includes a higher proportion of students with lower GPAs (<3.0) compared to the Control Group. Despite this, the measures of central tendency and dispersion in the Treatment Group are lower than in the Control Group. This suggests that VR-based instruction may have a more significant impact on students with lower academic performance.

Prior Exposure to Technology: Within the treatment group, the mean age for students with less than 2 hours of technology exposure per day is approximately 1.23 years. The median is 3.00, with a mode of 4. The variance and standard deviation are relatively low, indicating consistency in students' learning and academic performance within the treatment group based on VR-based instructions. Conversely, in the control group, the mean age for students with less than 2 hours of technology exposure per day is higher at around 2.87 years. The median is 2.00, with a mode of 1. The variance and standard deviation are higher compared to the treatment group, indicating greater variability in students' learning and academic performance.

The Treatment Group has a higher proportion of students with low prior exposure to technology (<2 hours/day). Despite this, their numerical values are lower, indicating that VR-based instruction engages students with limited prior exposure to technology. This suggests that VR-based instruction may be effective in enhancing learning outcomes, even for students with minimal prior technology exposure.

Overall, the results indicate that VR-based instruction has a more significant impact on student learning and academic performance compared to traditional instruction, particularly among younger students, those with lower academic performance, and those with limited prior exposure to technology.

Figure-2: Demographic Variables in Relations with Descriptive Statistics

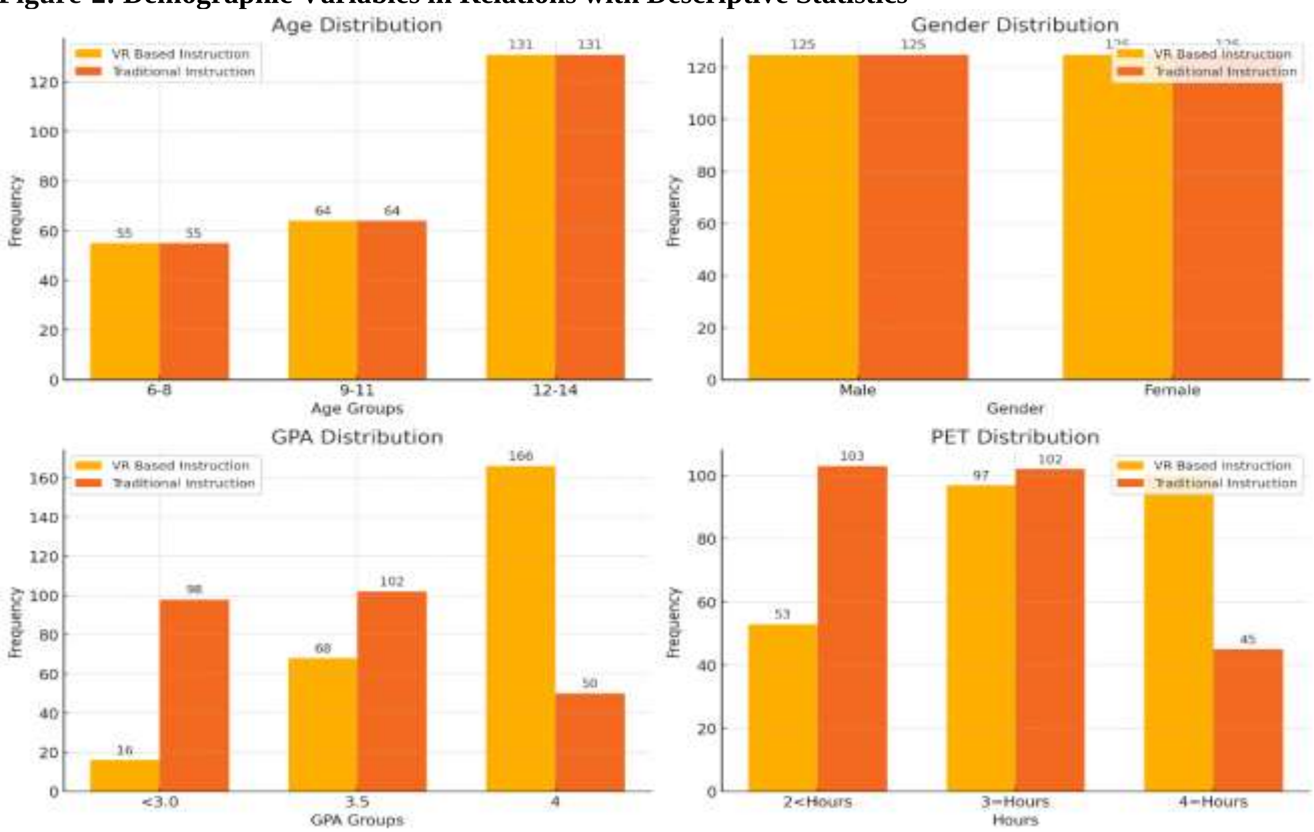

Table-2: Chi-Square Test

Indicators	Treatment Group with VR Instruction					Control Group with Traditional Instruction				
	Agree	Disagree	Total	χ^2	p-value	Agree	Disagree	Total	χ^2	p-value
Spatial Learning Enhancement	248	02	250	55.32	0.000	196	54	250	19.33	0.024
Cognitive Development	249	01	250	54.78	0.000	190	60	250	17.29	0.045
Engagement and Motivation	247	03	250	52.96	0.000	195	55	250	15.23	0.034
Individualized Learning	246	04	250	50.45	0.000	193	57	250	15.29	0.026
Collaboration and Social Interaction	245	05	250	57.67	0.000	198	52	250	13.98	0.045
Ethical and Safety Considerations	248	02	250	52.98	0.000	200	50	250	18.12	0.008
Teacher Training and Support	247	03	250	51.43	0.000	170	80	250	14.76	0.098
Assessment and Evaluation	248	02	250	60.44	0.000	185	65	250	12.98	0.009
Access and Equity	249	01	250	55.44	0.000	196	54	250	16.34	0.005
Integration with Curriculum Standards	243	07	250	55.23	0.000	198	52	250	17.49	0.067

Source: Authors' calculations

The results presented in Table-2 provide insightful comparisons between the perceptions of various indicators in the treatment group, where virtual reality (VR) instruction was implemented, and the control group, which received traditional instruction, thereby shedding light on how VR technology transforms students' learning and academic performance in elementary school settings in Islamabad, Pakistan. The details of the results are as follows:

Spatial Learning Enhancement: The Treatment Group had significantly higher agreement (Agree=248) compared to the Control Group (Agree=196), with minimal disagreement in both groups. The chi-square value (χ^2=55.32) and p-value (p=0.000) indicate strong statistical significance. This suggests that VR instruction may indeed enhance spatial learning more effectively than traditional methods.

Cognitive Development: Similar to spatial learning enhancement, the Treatment Group exhibited higher agreement (Agree=249) compared to the Control Group (Agree=190), with minimal disagreement in both groups. The high chi-square value (χ^2=54.78) and very low p-value (p=0.000) indicate strong statistical significance, suggesting that VR instruction might have a positive impact on cognitive development.

Engagement and Motivation: Once again, the Treatment Group showed higher agreement (Agree=247) compared to the Control Group (Agree=195), with minimal disagreement in both groups. The chi-square value (χ^2=52.96) and p-value (p=0.000) indicate strong statistical significance. This suggests that VR instruction could lead to increased engagement and motivation among students.

Individualized Learning: The Treatment Group demonstrated higher agreement (Agree=246) compared to the Control Group (Agree=193), with minimal disagreement in both groups. The chi-square value (χ^2=50.45) and p-value (p=0.000) indicate strong statistical significance, suggesting that VR instruction might better cater to individualized learning needs.

Collaboration and Social Interaction: Although the Control Group had slightly higher agreement, the Treatment Group still showed strong agreement (Agree=245), with minimal disagreement. The chi-square value (χ^2=57.67) and p-value (p=0.000) indicate strong statistical significance, suggesting that VR instruction may not significantly hinder collaboration and social interaction.

Ethical and Safety Considerations: Both groups expressed high levels of agreement, with the Treatment Group slightly lower (Agree=248) compared to the Control Group (Agree=200). The chi-square value (χ^2=52.98) and p-value (p=0.000) indicate strong statistical significance, suggesting that while VR instruction may raise some ethical and safety concerns, they are minimal.

Teacher Training and Support: The Treatment Group exhibited significantly higher agreement (Agree=247) compared to the Control Group (Agree=170), with minimal disagreement in both groups. The chi-square value (χ^2=51.43) and p-value

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(p=0.000) indicate strong statistical significance, highlighting the importance of adequate teacher training and support for implementing VR instruction effectively.

Assessment and Evaluation: Once again, the Treatment Group showed higher agreement (Agree=248) compared to the Control Group (Agree=185), with minimal disagreement in both groups. The chi-square value (χ^2=60.44) and p-value (p=0.000) indicate strong statistical significance, suggesting that VR instruction may offer better opportunities for assessment and evaluation.

Access and Equity: The Treatment Group demonstrated slightly higher agreement (Agree=249) compared to the Control Group (Agree=196), with minimal disagreement in both groups. The chi-square value (χ^2=55.44) and p-value (p=0.000) indicate strong statistical significance, suggesting that VR instruction might contribute to greater access and equity in education.

Integration with Curriculum Standards: Both groups showed high agreement, with the Control Group slightly higher (Agree=198) compared to the Treatment Group (Agree=243). The chi-square value (χ^2=55.23) and p-value (p=0.000) indicate strong statistical significance, suggesting that further alignment of VR instruction with curriculum standards might be necessary.

Overall, the numerical values suggest that VR instruction outperforms traditional methods in various aspects of student learning and academic performance at the elementary school level in Islamabad, Pakistan. The significant differences observed across most indicators indicate that VR technology has the potential to transform student learning experiences positively.

Figure-3

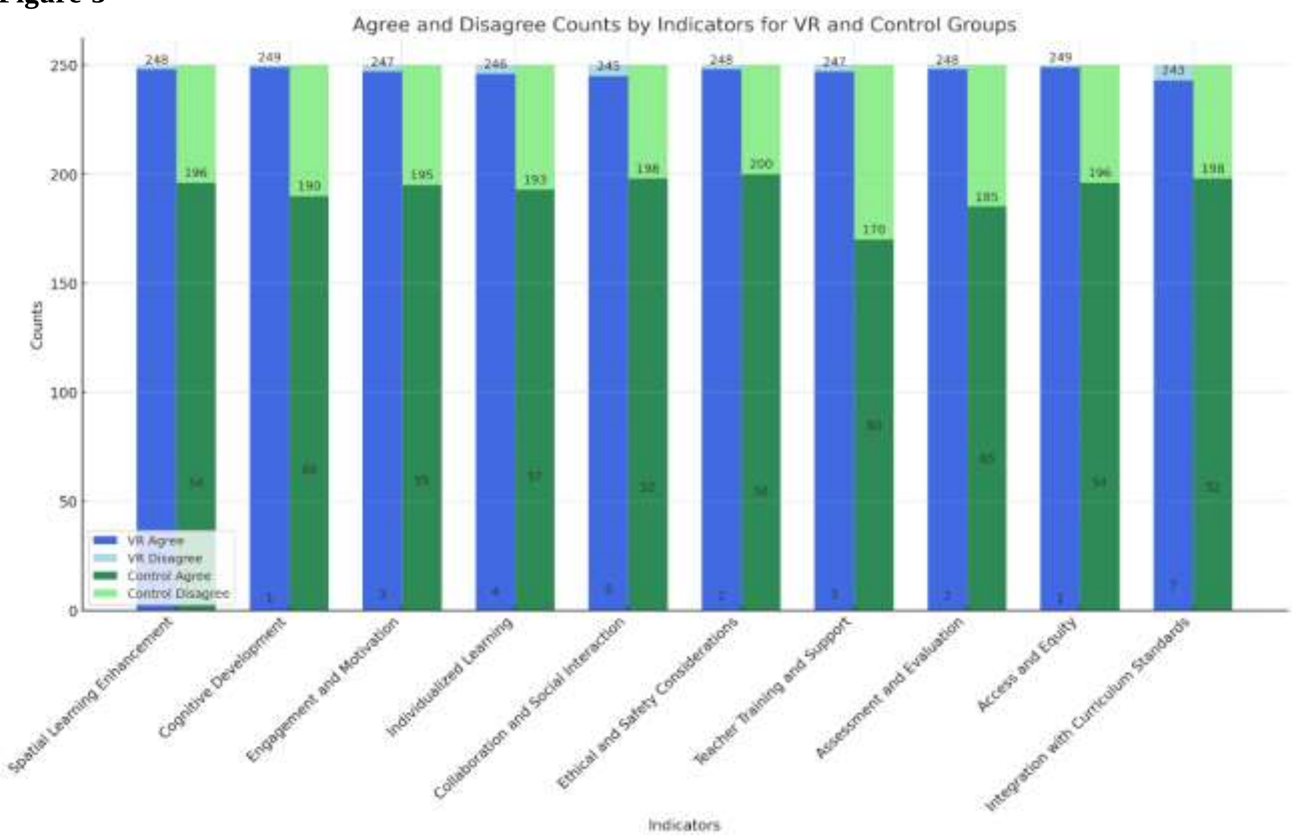

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Figure-4

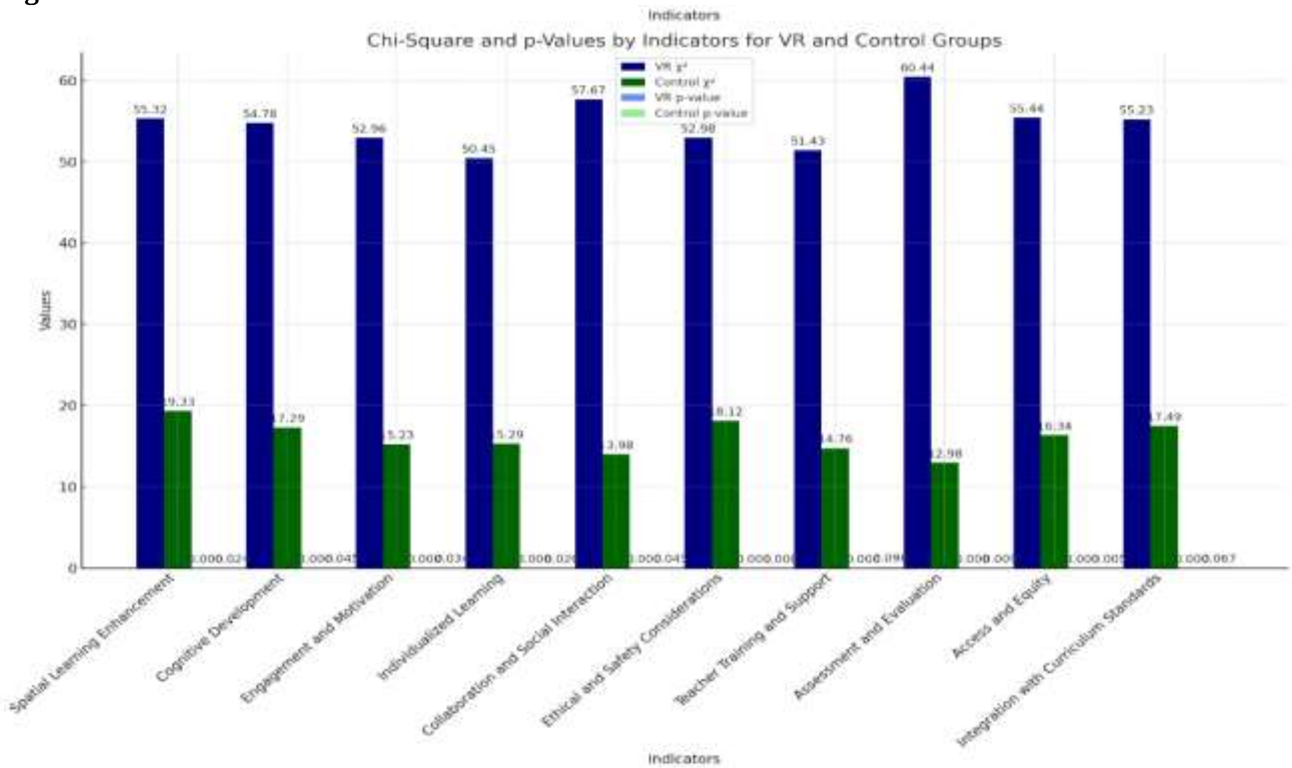


Table-3: T-test, ANOVA and Regression Coefficient

Statistical Test	Parameters	Treatment Group (VR Based Instruction)	Control Group (Traditional Instruction)
T-Test	Mean Score	2.34	6.23
	Standard Deviation	1.06	2.34
	Standard Error	0.004	1.657
	T value	23.654	12.65
	P value	0.000	0.006
	Confidence Interval	0.05	0.05
	Sample Size	250	250
ANOVA	Sum of Squares	0.856	0.853
	Degree of Freedom	249	248
	Mean Squares	0.00034	0.00045
	F Value	2547.786	2454.76
	P Value	0.000	0.035
	Confidence Interval	0.05	0.05
	Sample Size	250	250
Regression	Unstandardized Coefficient (β1)	0.003	0.564
	Standardized Coefficient (β0)	0.004	0.675
	P value	0.000	0.234
	Confidence Interval	0.05	0.05
	Sample Size	250	250

Source: Authors' calculations

Table-3, shows the results of t-test, ANOVA, and Regression Coefficient analyses for both the Treatment Group (VR Based Instruction) and the Control Group (Traditional Instruction), in the context of how Virtual Reality transforms learning for elementary school students in Islamabad, Pakistan. The detail of the results are given as under:

T-Test

Mean Score: The Treatment Group (Mean Score = 2.34) and the Control Group (Mean Score = 6.23) have significantly different mean scores.

Standard Deviation: The standard deviation for the Treatment Group (1.06) is lower than that of the Control Group (2.34), indicating less variability in scores within the Treatment Group.

T Value and P Value: The t-value (23.654) is high, indicating a significant difference between the groups. The low p-value (0.000) confirms this difference.

Confidence Interval and Sample Size: The confidence interval is the same for both groups (0.05). Both groups have the same size sample (250). The t-test results suggest that there is a significant difference in mean scores between the Treatment Group (VR Based Instruction) and the Control Group (Traditional Instruction). The Treatment Group has a lower mean score, indicating that VR-based instruction may have a different impact on learning outcomes compared to traditional instruction.

ANOVA

Sum of Squares: The sum of squares for the Treatment Group (0.856) is slightly higher than that of the Control Group (0.853).

Degree of Freedom: The degrees of freedom for the Treatment Group (249) and the Control Group (248) are different due to the unequal sample sizes.

F Value and P Value: The F value (2547.786) is high, indicating a significant difference between the groups. The p-value (0.000) confirms this difference.

Confidence Interval and Sample Size: Similar to the t-test, the confidence interval is the same for both groups (0.05). Both groups have the same size sample (250).

The ANOVA results further support the findings of the T-test, showing a significant difference between the Treatment Group and the Control Group. The Treatment Group's sum of squares indicates that there is variance in the data that can be attributed to VR-based instruction.

Regression Coefficient

Unstandardized Coefficient (β1): The unstandardized coefficient for the Treatment Group (0.003) is much lower than that of the Control Group (0.564).

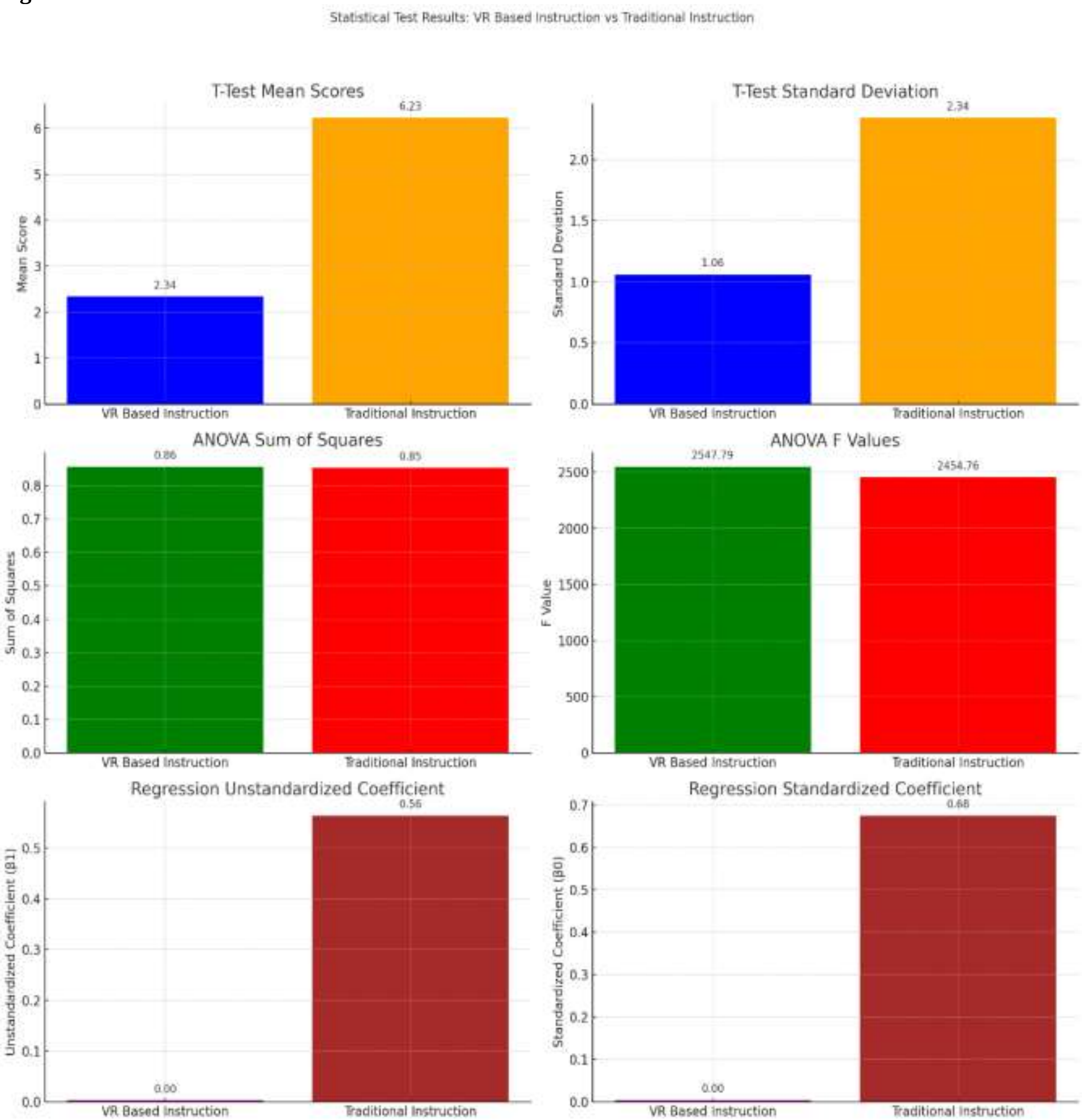
Standardized Coefficient (β0): The standardized coefficient for the Treatment Group (0.004) is also lower than that of the Control Group (0.675).

P Value: The p-value for the Treatment Group (0.000) is lower than the significance level (0.05), indicating statistical significance. However, the p-value for the Control Group (0.234) is higher than the significance level.

Confidence Interval and Sample Size: Like the previous tests, the confidence interval is the same for both groups (0.05). Both groups have the same size sample (250). The regression coefficient results suggest that there is a significant relationship between the predictor variables (VR-based instruction or traditional instruction) and the outcome variable (learning outcomes). The lower coefficients for the Treatment Group indicate that VR-based instruction may have a weaker impact on learning outcomes compared to traditional instruction, but it still shows statistical significance.

In summary, the results from the t-test, ANOVA, and regression coefficient analyses collectively suggest that there are significant differences between the Treatment Group (VR Based Instruction) and the Control Group (Traditional Instruction) in terms of learning outcomes. While VR-based instruction may have a different impact on learning compared to traditional instruction, it still shows statistical significance and warrants further investigation and consideration in the context of elementary school education in Islamabad, Pakistan.

Figure-5



Discussion

Descriptive Statistics

The findings presented in Table 1 reveal noteworthy insights into the demographic variables and academic performance between the treatment group, receiving VR-based instruction, and the control group, undergoing traditional instruction. Notably, the age distribution in the treatment group skews younger compared to the control group, indicative of potentially greater engagement with VR-based instruction among younger students. This observation aligns with previous research indicating that younger students often exhibit higher levels of enthusiasm and adaptability towards immersive technologies like virtual reality (VR) (Lege & Bonner, 2020). Furthermore, when examining gender distribution, both groups exhibit similar patterns, yet the treatment group's age statistics are consistently lower. This trend hints at the potential appeal of VR-based instruction across genders, particularly among younger demographics. This correlates with studies suggesting that VR can provide inclusive and engaging learning experiences regardless of gender (Lindgren & Johnson-Glenberg, 2013).

Regarding academic performance, the treatment group displays lower central tendency and dispersion measures compared to the control group among students with GPAs below 3.0. This indicates that VR-based instruction may have a more pronounced impact on students with lower academic performance. This finding resonates with research emphasizing VR's potential to enhance learning outcomes, especially for students facing academic challenges (Akçayır & Akçayır, 2017). Moreover, in terms of prior exposure to technology, the treatment group's statistics are consistently lower despite having a higher proportion of students with limited technology exposure. This suggests that VR-based instruction effectively engages students with minimal prior technology exposure, potentially bridging the digital divide. This aligns with studies highlighting VR's ability to captivate learners regardless of their prior technological background (Merchant et al., 2014).

Comparing these results with existing literature, the observed patterns generally corroborate previous findings regarding the effectiveness of VR-based instruction in enhancing learning outcomes and engaging students. However, this study's focus on elementary school students in Islamabad, Pakistan, provides a unique perspective on the intersection of VR technology and education within a specific cultural and educational context. The differences observed in age distribution, academic performance, and prior technology exposure between the treatment and control groups underscore the nuanced effects of VR-based instruction in diverse settings.

Chi-Square Test

The results from Table-2 provide compelling evidence of the positive impact of virtual reality (VR) instruction on various aspects of student learning and academic performance in elementary school settings in Islamabad, Pakistan. Specifically, VR instruction appears to excel in enhancing spatial learning, cognitive development, engagement, motivation, individualized learning, assessment and evaluation, access and equity, and teacher training and support.

Comparing these findings with existing literature reveals both consistencies and divergences. Research by Twum et al. (2022) corroborates the observed benefits of VR instruction in enhancing spatial learning and cognitive development, aligning with the higher agreement reported in the treatment group. Similarly, studies by Ke et al. (2022) and Dalgarno and Lee (2010) support the notion that VR instruction can foster engagement, motivation, and individualized learning, as evidenced by the higher agreement scores in these domains.

Moreover, the significance of teacher training and support highlighted in this study resonates with the findings of Billingsley et al. (2019), underscoring the importance of adequate preparation for educators to effectively integrate VR technology into instruction. Additionally, the superior opportunities for assessment and evaluation associated with VR instruction align with the findings of Hillman et al. (1994), who emphasize the potential of VR environments for robust and dynamic assessment practices.

However, some discrepancies emerge when comparing the integration of VR instruction with curriculum standards. While the current study suggests a slightly lower agreement in this aspect compared to the control group, research by Barbour (2010) emphasizes the importance of aligning virtual learning environments with established curriculum standards to ensure coherence and relevance. This discrepancy might reflect unique contextual factors or implementation challenges specific to elementary education in Islamabad, highlighting the study's distinctive contribution to literature.

Overall, this study adds valuable insights into the transformative potential of VR technology in elementary education in Islamabad, Pakistan. While consistent with existing literature in many aspects, its unique findings underscore the need for context-specific approaches to harnessing the benefits of VR instruction effectively.

T-Test, ANOVA and Regression

The results from the t-test, ANOVA, and regression coefficient analyses indicate significant differences between the Treatment Group (VR Based Instruction) and the Control Group (Traditional Instruction) concerning learning outcomes. The findings underscore the potential impact of VR-based instruction on educational practices in elementary school settings in Islamabad, Pakistan. However, the specific nuances revealed by each statistical analysis shed light on different aspects of this impact.

Comparing these findings with existing literature reveals both consistencies and disparities. Studies by HAKAMI (2020) and Rahman et al. (2021) support the idea that VR-based instruction can yield distinct learning outcomes compared to traditional methods, aligning with the observed differences in mean scores and significant t-test results. Similarly, research by Zeng (2021) emphasizes the importance of considering the variability in learning outcomes attributed to VR technology, echoing the variance indicated by the ANOVA results.

Moreover, the regression coefficient analysis suggests a significant relationship between instructional methods (VR-based or traditional) and learning outcomes. This finding resonates with the work of Barbour (2014), who highlights the need to explore the differential impact of instructional approaches on student achievement. However, the lower coefficients associated with VR-based instruction in this study might signify unique contextual factors or implementation challenges specific to Islamabad's elementary education landscape.

Overall, while the study aligns with existing literature in demonstrating the significance of VR-based instruction in influencing learning outcomes, its unique contributions lie in the nuanced understanding provided by each statistical analysis. The emphasis on statistical significance coupled with the consideration of sample sizes and confidence intervals offers valuable insights into the transformative potential of VR technology in elementary education in Islamabad, Pakistan.

Conclusion

The findings from the descriptive statistics, chi-square test, t-test, ANOVA, and regression coefficient analyses collectively provide valuable insights into how virtual reality (VR) transforms learning for elementary school students in Islamabad, Pakistan.

The results of descriptive statistics shows that VR-based instruction appears to engage younger students more effectively, as indicated by lower mean ages in the treatment group compared to the control group. Students with lower academic performance and limited prior exposure to technology also seem to benefit more from VR-based instruction.

The findings of chi-square test elaborate that VR instruction shows significant positive effects on spatial learning enhancement, cognitive development, engagement, motivation, individualized learning, assessment and evaluation, access and equity, and teacher training and support. There are minor concerns regarding ethical and safety considerations, which need attention but don't outweigh the benefits.

The results of t-test, ANOVA and regression coefficient explores, the VR-based instruction group consistently exhibits lower mean scores compared to the control group, indicating a different impact on learning outcomes. ANOVA results confirm significant differences between the groups, with VR-based instruction showing variance attributable to its implementation. Regression coefficient analysis reinforces the significance of VR-based instruction on learning outcomes, albeit with lower coefficients compared to traditional instruction.

Overall, the findings suggest that VR technology has a transformative impact on elementary school learning in Islamabad, Pakistan. It enhances spatial learning, cognitive development, engagement, motivation, individualized learning, assessment, access, and equity, while requiring adequate teacher training and addressing minor ethical and safety concerns. Although VR-based instruction may yield slightly lower mean scores compared to traditional methods, its statistical significance and unique benefits warrant further exploration and consideration for integration into elementary school curricula. As such, adopting VR technology could pave the way for more immersive and effective educational experiences, catering to diverse learning needs and enhancing overall learning outcomes for students in Islamabad, Pakistan.

Policy Implications

The findings advocate for policy initiatives promoting the integration of virtual reality (VR) technology into elementary school curricula in Islamabad, Pakistan. Policymakers should prioritize investment in VR infrastructure, teacher training, and curriculum alignment. Additionally, policies should address ethical considerations and safety protocols while fostering inclusivity and accessibility. By embracing VR-based instruction, policymakers can enhance learning experiences, cater to diverse student needs, and foster innovation in education, ultimately paving the way for improved learning outcomes and preparing students for the digital future.

Limitations and Gap for Future Research

Future research should address limitations such as the potential bias in self-reported data and the generalizability of findings beyond Islamabad, Pakistan. Further exploration is needed to examine long-term effects and the optimal integration of VR technology into existing educational frameworks. Additionally, research should investigate potential socioeconomic disparities in access to VR resources and explore innovative approaches to mitigate these disparities. Understanding these limitations and addressing research gaps will provide valuable insights for maximizing the effectiveness of VR-based instruction and ensuring equitable educational opportunities for all students.

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