Exploring Interactive STEM in Online Education through Robotic Kits for Playful Learning

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Abstract- A method known as "playful learning" is one that makes use of various forms of play to facilitate discovery learning as well as problem-solving. Playful learning may be difficult to implement in an online environment designed to teach subjects related to science, technology, engineering, and mathematics (STEM), particularly at times like the COVID19 shutdown. This obstacle will be conquered during this research, as will the question of whether or not it is beneficial to use entertaining methods, such as combining aspects of game design and robotics, in order to teach STEM topics within the context of an online learning environment. This research analyzes the impact that adopting fun learning in online STEM education has on the level of student engagement as well as the amount that they learn. According to the findings of this study, increasing the amount of cognitive, emotional, and behavioral engagement among students by having them playfully learn with robots resulted in greater overall levels of engagement.

Index Terms- STEM, interactive education, robotic kits, playful learning, comparative analysis, hybrid learning

I. Introduction

A STEM integrates science, technology, engineering, and math into applied curriculum. STEM integrates practical knowledge. STEM education prepares students for the digital age. STEM teaches using real-world examples. This method helps pupils relate the classroom to real-world use of information. This enhances STEM literacy [1]. Playful learning promotes discovery and problem-solving. Playful learning is difficult to incorporate into an online STEM education setting because it involves physical activity. This project intends to solve this obstacle and explore ways to make STEM e-learning engaging and effective to encourage and engage students. STEM research involves robots. Playful learning with robotics to teach STEM ideas online is understudied. Technology-dependent "Generation Alpha" needs a creative, innovative education. Students need an active learning environment to become expert learners. Pakistani kids are talented but lack suitable learning conditions. COVID-19 disrupted education for over a billion students. Homeschooling and e-learning made learning settings difficult to create after school closures. Online student motivation is difficult, especially in STEM topics that require tangible learning tools. Playful online STEM learning stimulates students and is an option during pandemics. With supervision, quality assurance, feedback, lecture recording, data monitoring, and student performance tracking, it helps future research and improves blended learning in schools. COVID-19 interruptions are used to evaluate an online STEM learning environment. To help Pakistani students become innovators, scientists, and creators. This project investigates if playful robotics might help students learn STEM online. Time and COVID limits prevented them from using physical robots, so they employed virtual ones. The study examines how this affects online STEM student engagement and learning. The study incorporates games to make studying fun. It examines how online STEM learning influences students' feelings, thinking, and physical activity. STEM was taught using game components on a robotics website. During the COVID-19 lockdown, students coded virtual robots and solved problems, comparing playful and traditional instruction. This study used a quasi-experimental design with a control and an experiment group. Army Public Schools in Rawalpindi and Nowshera sent 50 Grade 6 and 7 pupils per group, totaling 100. The research showed that incorporating robotics and game aspects for entertaining learning enhanced student engagement, since the two groups had significantly different outcomes. "Our world is changing faster than ever.

Future generations will encounter a constant stream of fresh difficulties and unforeseen obstacles. Much of what students learn now will be obsolete tomorrow. They must develop creative solutions to the unanticipated issues that will inevitably come in their life to succeed. Creative thinking and action will determine their success and happiness. Knowledge is not enough—they must learn to apply it imaginatively [2]. Interest-based projects help short-attention students focus on normal classrooms. Seymour Papert called it "hard fun." When students find their passions, they are willing to tackle difficult tasks. Research suggests that catching student attention, facilitating deep learning, and minimizing cognitive burden increase engagement. Improved educational performance follows. Teachers use robotics to integrate STEM and teach 21st-century skills like creativity, collaboration, critical thinking, computational thinking, and communication. Theoretical Framework Robotics learning is linked to constructivism and constructionism. Piaget's constructivism explains how people learn from their experiences. Based on Piaget's concepts, Papert introduced constructionism, which claims children learn best by creating and sharing something significant. Build robots to build 21st-century STEM abilities through exploration and hands-on learning. Constructivism and constructionism guide a learning environment where students experiment, investigate, and design items to develop critical thinking and inventiveness. Constructivism includes allowing kindergarteners use Play-Doh to make meaningful objects. However, constructionism learning theory supports students working together to design a plant watering robot with their teacher. Researchers define teacher and learner contexts in both theories: Constructivist instructor: This instructor encourages students to learn at their own speed and solve problems. Students control their learning by making something meaningful. Teaching begins with the teacher and then ends without intervention. Constructionist instructor: The instructor creates a collaborative learning atmosphere. Students choose a hard and meaningful endeavor and take ownership of achieving it. The instructor helps pupils achieve their goals by guiding and facilitating learning. The learning theories can be linked to Table 2.1's qualities.

Multidisciplinary robotics can improve STEM learning by establishing constructive learning environments [3]. Playful education aligns with constructivist learning theory and gamification. Gamification is commonly used to motivate and improve learning. According to researchers [4], games are more dynamic than traditional classrooms because they engage students with visually appealing content and enjoyable experiences. Multi-dimensional roleplaying in games promotes knowledge development and deep comprehension, called "guided discovery." Students assess their thinking and build knowledge with Serious Educational Games (SEGs).2. Robotics in STEM

Theories	Attributes			
	Experience	Artifact	Collaboration	Use of Tools, Media and Context
Constructivism	Knowledge is inherited from experience. Knowledge is constructed by new experience	Construct a Personal Artifact	Not necessary	Not necessary
Constructionism	Knowledge is inherited from experience. knowledge is constructed by new experience	Construct an Artifact which is meaningful	Sharing Creativity	Learning is enhanced by use of media and contextual understanding

Figure 1 Constructivism vs Constructionism

According to STEM education research, compelling classroom content increases student engagement. Robotics can inspire STEM-related activities in pupils [5]. Robotics also engages teachers. Robotics-based professional training helps teachers learn constructionist methods to improve student critical thinking. Robotics makes STEM subjects more concrete and interesting. Robotics activities make math and science more meaningful [6]. Robots enhance traditional schooling by adding excitement and hands-on learning [7]. Educational robots like ER4STEM inspire students to explore STEM jobs like entrepreneurship and research. Educational robotics (ER) teaches STEM, scientific analysis, design, problem-solving, creativity, and cooperation. It motivates students and boosts confidence, creativity, and teamwork. Online robotics can plan and model real robots, boosting math and programming language understanding. Real robots can represent mathematical concepts and promote affective involvement.2.2.1. Lego Robotics Lego robots enhance home-based learning by teaching youngsters problem-solving and science [8]. Building Lego EV3 robots improves spatial perception, mathematical reasoning, design thinking, engineering, and technology while making learning fun [9]. Lego

Mindstorms lets 6-year-olds build programmable robots with blocks. It teaches coding, logic, and engineering, while the little pieces challenge younger kids and improve motor skills and coordination. Arduino Robotics Educational robots employing Arduino boards encourage student invention and motivation through collaborative learning. Starting with easy problems and increasing difficulty is best for young learners. Effective learning requires theory and practice, and Arduino helps achieve this. Its free, user-friendly program works with multiple operating systems [10]. Elegoo Smart Robot Car Kit, Makeblock Educational Robot Kit, Codibot, Arduino Robot, and more are Arduino Robotics kits.2.2.3. Robotics alternative kits Robotics kits for STEM education include Arduino, Lego, and others. Like the micro: bit-based "Robo bit buggy," Raspberry Pi-powered "GoPiGo 3" robot car kit. The "Sun founder PiCar" is another Raspberry Pi robotics kit. The commercial robot "Cozmo" is a great tool for youngsters and adults to learn creative coding because to its user-friendly interface. Finally, the "Meccano Meccaspider" robot kit has 291 components and can be controlled by instructional software. Robotics and STEM enthusiasts can choose from these kits. Web-based applications help learners overcome time and space constraints. Many online platforms offer STEM-focused education in response to the increased relevance of media literacy as a 21st-century skill. Some significant STEM education online environments:1. "VEX code VR": This block-based platform lets users code virtual robots like Scratch.2. "Open Roberta® Lab": A free, block-based robot programming environment with many sensors.3. "simulator.io": Online logic circuit maker.4. "Tinkercad": This free online tool allows 3D modeling and printing. It teaches solid geometry interactively. One form, "Tinkercad circuits," lets Arduino users design, program, and simulate fundamental electrical circuits.5. "BrainPop": BrainPOP delivers animated films, quizzes, and activities matched with school curricula for K-12 pupils, including STEM. Scratch and Minecraft are popular STEM-focused internet platforms. Here are thorough critiques of these two platforms from this thesis.2.3.1. ScratchThe 4Ps—Projects, Peers, Passion, and Play—guide Mitchel Resnick's Scratch learning environment's design to encourage creativity in young learners. Scratch lets kids create tales, animations, and games by connecting coding blocks like Lego pieces. Scratch's multiple possibilities make learning programming fun and fast for all ages. Crumble, another online application, mixes block programming software with hardware to help children build electronics. Beginner coders should start with Scratch before moving on to Crumble and Arduino. For non-programmers of all ages to learn to code, Scratch is best [11]. Research shows that Scratch can smoothly connect many hardware components, allowing for hands-on learning. Lego Robots can be programmed in Scratch. For instance, "Lego WeDo" lets kids aged 7–11 design and program robots using block-based coding. By installing an online extension, this kit works with Scratch. Its Bluetooth connection to Scratch promotes constructionism learning. Scratch and Lego make programming and robotics easy to teach in primary school. To connect "Lego Mindstorms NXT" to Scratch, use "Enchanting". "Lego Mindstorms Education EV3" may be coupled to Scratch to extend possibilities and let students make robotic puppets and more. Carnegie Mellon's CREATE lab's little, rudimentary robot "Finch," connects via USB and needs the Birdbrain robot server. It integrates well with Scratch since it supports multiple programming languages and environments. "Hummingbird" is a robotics kit with lights, sensors, and motors that lets kids build robots with any materials. It uses the Birdbrain server and has a low-floor, high-ceiling approach, making it suited for beginners and experienced engineering and programming learners. The "micro: bit" is a small circuit board that encourages coding and creative learning in children. Enabling Scratch extensions lets you program it. The "S4A" variant of Scratch allows for Arduino programming, expanding its capabilities to hardware. The "Makeblock" programming environment combines Scratch's visual language with Arduino for a smooth learning experience. Raspberry Pi-powered "GoPiGo3" robot cars. The kit is user-friendly and may be programmed using Scratch or other languages, offering learners flexibility. The visual programming language "Scratch Jr" teaches 5–8-year-olds to code before they can read. Kids this age can do creative projects. Several commercial educational robots that work with Scratch and Scratch Jr are: "Dash and Dot," for ages four and above, can link to Scratch Jr over Bluetooth using an extension. In Scratch Jr, "Sphero and Ollie" robots can move and change colors. The

"Light Play" initiative lets participants experiment with light and colors. Scratch Jr may be used to program "KIBO" another robot for kids aged 4–7. Since Scratch is a popular learning platform, competition has grown as individuals realize its value. The program's playfulness boosts creativity and learning. Some of the initiatives in the table below use robots and gamification to improve learning.

Platform	Age	Coding		Build Games	Gamification	Hardware integration	Free
		Block	Textual				
Snap	12+	Yes		Yes		Yes	Yes
Blockly	8+	Yes					Yes
Stencyl	12+	Yes		Yes			Yes
App inventor	10+	Yes		Apps		Yes	Yes
Game Salad	13			Yes			Trial
Tynker	5+	Yes	Yes		Yes		Trial
Code.org	K- 12	Yes	Yes	Yes	Yes		Yes
Code monkey	K-8	Yes	Yes		Yes		Trial
Code Kingdoms	8+	Yes	Yes	Yes			Trial
Code Combat	Gr 5+		Yes		Yes		No
Alice	Gr 6+	Yes	Yes	Yes			Yes
Kodable	4-10	Yes	Yes		Yes		Trial

Figure 2 Competitor of Scratch

It's the foremost preliminary step for proceeding with any research work writing. While doing this go through a complete thought process of your Journal subject and research for it's viability by following means:

Read already published work in the same field. Goggling on to the topic of your research work. Attend conferences, workshops, and symposiums on the same fields or on related counterparts. Understand the scientific terms and jargon related to your research work. Minecraft is a massive 3D block-based game where players acquire materials and build structures. One of the most popular video games, it has over 100 million users. Minecraft's rich material corresponds with traditional and modern learning theories; thus, educators worldwide use it. The release of "Minecraft for Education Edition" (Minecraft Edu) has helped it succeed by providing compelling educational content and tools to assist students learn programming basics and apply STEM coding abilities. Teaching conditions, functions, coordinates, and coding to pupils of all ages promotes computational thinking [12]."Hour of Code" Minecraft uses game-like graphics, an immersive world with a plot, tutorials, and a block-based programming language like Scratch to gamify programming education. Teachers use Minecraft to teach STEM. It shows chemical stability, cell properties, and equations in science, biology, and arithmetic. Virtual experiences allow for unique art and history learning. Building a Minecraft calculator requires electrical circuits, calculations, and design, incorporating engineering, mathematics, and design. Students who play Minecraft explore its huge virtual world without fear. Teachers who integrate learning into the curriculum help students build relevant knowledge. Minecraft is a popular educational game. The "Minecraft for Education Edition" teaches programming and computation. Minecraft's "Hour of Code" toys with code. Minecraft helps teachers teach STEM courses, and "Code Builder" and "Computer Craft Edu." let pupils play with robotics. Minecraft players have made Raspberry Pi-controlled robotic arms and other projects with Arduino, Raspberry Pi, and Lego NXT. "MCreator Link" connects hardware to Minecraft for more interaction. Exploration and play help youngsters learn and solve problems in informed learning. Playful learning is popular with children but has less research for adults. Play is innately motivated and prioritizes process over result. It helps develop language, emotion, imagination, and social interaction, as well as brain reasoning and creativity. To satisfy the needs of future generations, schools must focus on innovation and creativity employing new technology. Students require creative and critical thinking skills to solve real-world problems, thus traditional educational approaches may not work. Playful and real learning improves knowledge and innovation. Play helps kids learn by encouraging curiosity and using all five senses to explore their surroundings. Playful learning, within the "magic circle," involves accepting failure, giving feedback, and increasing intrinsic desire. Students grow resilient to failure, take risks, and focus on learning problems, increasing creativity and innovation. Learner's gain meaning from intrinsically motivated involvement. Role play, making, building, tinkering, experimentation, and learning from mistakes are playful learning methods. They motivate students, spark interest, and reward task completion. Playful learning turns students into knowledge builders. It uses game design to motivate and engage students. Game design includes mechanics, visuals, story, incentives, music, content, and skills. Gamified games motivate and engage students. Kintsakis & Rangoussi discovered that graphics, game atmosphere, and aspects interested and engaged students in their intervention. Animation and graphics enhance subject comprehension. Serious Educational Games (SEGs) simulate real-world experiences to teach problem-solving. SEGs designed by teachers improve student performance, especially in science. Video games teach pupils digital literacy, invention, multitasking, logic, sociability, and bargaining, which are widespread nowadays. Game-based teaching improves student involvement, attention, and recall. Complex tasks, learner roles, diverse goal alternatives, and learner control make games interactive. Games with challenge, fantasy, intricacy, and control are engaging. These factors make game-based learning effective in education. Although digital production tools are developing, early childhood education does not emphasize digital content creation or higher-order thinking. Emerging technologies and smart teaching approaches can improve young children's learning. Researchers have investigated using robotics to teach arithmetic, physics, programming, and engineering design. These studies rarely identify the math, science, and technological skills pupils should learn from robotics programs. Game-Based Learning (GBL) in e to articulate the research work with ideas gathered in above steps by adopting any of below suitable approaches:

In this approach combine all your researched information in form of a journal or research paper. In this researcher can take the reference of already accomplished work as a starting building block of its paper.

This approach works the best in guidance of fellow researchers. In this the authors continuously receives The literature review has identified a research problem that underscores the lack of research on the online instruction of STEM concepts through a playful learning approach. This is particularly concerning considering the difficulties presented by the COVID-19 pandemic, which restricts the availability of physical learning aids in STEM education and mandates remote learning. Additionally, in every area of research an educated guess will help resolve many problems for example in elementary school, whether in the classroom or online, can boost student engagement and STEM learning results. This area needs more research. Gamification commonly inspires students through external prizes, but its internal motivation remains unexplored. Collaboration, problem-solving, extracurriculars, and Lego robots are typically associated with educational robotics (ER) [13]. Robotics projects normally prioritize technology and engineering over science and math. ER efforts focus more on IT than STEM education. Teachers use ER in classes. Further research will reveal ways teachers can use digital technology effectively. Game-based learning research is still in its infancy, although some studies have shown that games can encourage students. STEM research includes using robotics and online learning platforms like Scratch and Minecraft to teach STEM, according to the broad literature evaluation. Limited research exists on leveraging robotics or games to teach STEM concepts to young learners online, keeping them intrinsically motivated and improving learning outcomes as both experiential learning and games enhance satisfaction level of a student [14].

II. Methodology

freelancing but research is required to resolve this issue and develop an engaging e-learning environment that educates and motivates students [15]. The research proposal delineates the comprehensive notion of playful learning in the field of education, which incorporates tactics such as fostering a positive attitude toward failure, offering constructive criticism and assistance, and augmenting intrinsic motivation during learning exercises. The plan classifies various tools and technologies that foster a playful learning environment, such as simulations, board games, online games, and problem-solving exercises. It also incorporates strategies like storytelling and fantasy, all of which contribute to the overall learning experience. The objective of this research design is to incorporate these strategies, methods, and tools into a comprehensive design framework that is founded on the tenets of game-based learning. The selected framework, which was put forth by Jan L. Plass, Bruce D. Homer, and Charles K. Kinzer, integrates cognition and emotion to promote user involvement in e-learning platforms. By incorporating game design elements, the framework generates a variety of engagements that cultivate playful learning.

Methods	Explanation	Examples
Tools	Technologies and objects that can be used in the creation of a playful learning environment	• online games • simulations • board games
Techniques	Teaching and learning methodologies that foster play	• role-playing • problem solving • challenges • treasure hunts • puzzles
Tactics	Procedures and qualities that stimulate playfulness	• storytelling • fantasy • mystery

Figure 3 Tools, techniques and Tactics used.

The framework chosen to implement for this study is proposed by Jan L. Plass, Bruce D. Homer and Charles K. Kinzer. This framework describes types of engagement that foster playful learning and the game design elements that contribute to these engagement domains. Effects and cognition help define human interactions. Affect refers to feelings and emotional capacities of human beings whereas cognition has to do with mental models and thinking capabilities. The adapted framework aims to integrate these philosophies in the educational domain to foster motivated learning. This integrated framework is specifically designed for implementation in e-learning platforms. The diagram below depicts the role of affect and cognition that stimulate learning through elements of game design to create different types of engagements that enable playful learning.

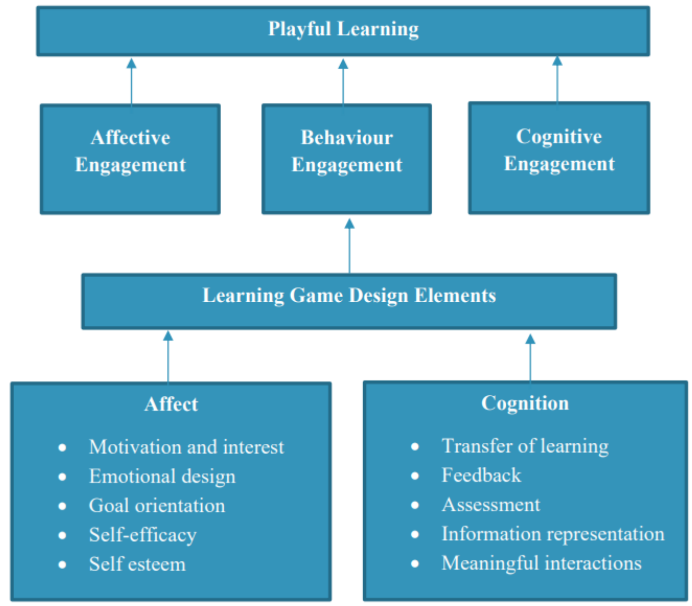

Figure 4 Theoretical Framework.

This study aimed to use playful learning strategies to teach STEM ideas and assess student participation in an online educational setting. The issue was 'speed, distance and time'. A quasi-experimental investigation was done. Post-test-only control and experimental groups were used. The quasi experiment was conducted on 11–14-year-old kids to determine if a fun approach to learning affected their interest in STEM ideas taught online. Students in Grades 6 and 7 from Army Public Schools in Rawalpindi and Nowshera were selected for the control and experimental groups. For a fair comparison, Grade 6 and 7 children from Army Public School Fort Road, Rawalpindi, and Army Public School Iqbal, Nowshera were selected. These students were then split into control and experimental groups. Different locations were chosen to accommodate diverse learners. All sections were taught the same topic by the researcher, with different pedagogy for control and experimental groups to guarantee uniformity. Topic-specific learning objectives were consistent across all sections. Students learned about speed, distance, and time utilizing a practical, interdisciplinary approach and analogies from daily life to reinforce STEM ideas in both groups. Both control and experimental groups had 50 individuals. Table summarizes participant demographics.

Categories	Schools		Grade		Group	
	APS Fort Road (Rawalpindi)	APS Iqbal (Nowshera)	Grade 6	Grade 7	Control	Experimental
No. of Participants	61	39	54	46	50	50

Figure 5 Participant's Demographic.

This study compared playful pedagogy to standard teaching techniques in online learning during COVID-19 lockout. The study focused on STEM education using robotics. This study aimed to determine if using technology to enhance playful learning strategies may significantly boost student engagement. Thus, the following questions were created to facilitate study.

Research Question 1: Does using game design features in online STEM teaching improve learner engagement?

Research Question 2: Does STEM studying online work? The integrated design framework lists many learner engagements. After examining engagement, which was further separated into affective, physical (behavior), and cognitive categories to answer our first research question. To answer our second study question, we chose the post-test score of students. To evaluate engagement levels between control and experimental groups, exploratory data analysis is a visual approach to data analysis. Our inquiry will focus on graphical representation of data and comparing results, as a statistical method is not necessary to prove a hypothesis. We propose the following hypothesis to evaluate learning outcomes in online STEM education.H0: Post-test scores are similar for playful and traditional methods. Playful and standard post-test scores are not similar. This study used experimental research, which is classified as quantitative. Selecting quasi-experimental study. In contrast to laboratory research, quasi-experimental or field research is undertaken in a natural setting. The variables are isolated, controlled, and changed to address the study topic. However, unlike experimental designs, the researcher does not have full control over the research setting (experimental conditions or extraneous variables). Social science research often uses quasi-experimental designs for non-random and inconvenient participant selection. This study used non-equivalent control group post-test only. A non-equivalent group design is a quasi-experiment that assesses the impact of treatments allocated to groups of individuals nonrandomly. Studies using this research design perform the intervention for the experimental group. Following the intervention, the findings are compared to the control group and analyzed. A control group is used to assess study results without intervention. The population sample under research intervention includes the experimental group. In this study, the control and experimental groups use different pedagogical methods. The control group is taught using traditional online methods during COVID-19, while the experimental group is taught utilizing playful pedagogy and robotics to engage students. Both groups are taught the same STEM topic, "speed, distance, and time," by the same instructor to ensure fairness in the study. Post-tests gather data from control and experimental groups. An engagement survey was conducted to measure student involvement, while an MCQ-based test was given to both groups to evaluate learning. The post-test findings are used to interpret changes because of the intervention. The STEM education study focused on "Speed, Distance, and Time".

The objective of this research was to assess and contrast the efficacy of playful pedagogy and conventional teaching approaches in the context of online STEM education, specifically robotics, amid the COVID-19 closure. The objective of this study was to examine whether the integration of game design elements into interactive learning techniques could have a substantial impact on learner engagement. The investigation was guided by the formulation of two research questions: Research Question 1 investigated the effects of integrating game design elements into creative learning on learner engagement. In contrast, Research Question 2 examined the extent to which learning outcomes were achieved in online STEM education. Engagement was recognized as a crucial variable to resolve these inquiries; it was classified into three dimensions: affective, physical (behavior), and cognitive. Furthermore, learning outcomes were evaluated in the study through the analysis of students' performance on post-tests. The methodology employed in this study was an experimental research design, more precisely a quasi-experimental study that utilized a post-test only design with a non-equivalent control group. The pedagogical approaches utilized in the control and experimental groups were dissimilar. While the control group was instructed using conventional online methods, the experimental group benefited from the integration of robotics concepts and playful pedagogy. Educational equity was maintained as both cohorts addressed the subject matter of "Speed, Distance, and Time" in STEM. Data collection was accomplished through the administration of post-tests, which comprised an engagement survey and multiple-choice questions. The data were analyzed utilizing non-parametric tests, specifically the Mann-Whitney Test, which was selected in consideration of the data's non-normal distribution. The primary objective of this study was to investigate the effects of playful pedagogy on learner engagement and learning outcomes specifically within the domain of online STEM education.

III. Data Analysis

The design experiment was followed by post-tests from control and experimental groups. Data was collected from Google Forms and tabulated in Excel. SPSS was used for statistical testing and exploratory analysis. Total sample size was 100, including 50 in each control and experimental group. To address our study questions, we split and analyzed the data. Students completed an engagement survey after the research intervention to determine engagement. The engagement survey measured behavioral, cognitive, and affective engagement. Participants provided data via Google Forms. The survey aimed to investigate the impact of game design components on student engagement in online STEM education. We used exploratory data analysis (EDA), a data science methodology that uses data visualization to analyze and summarize data sets, to analyze the survey data. Plotting data showed control and experimental group engagement disparities. Engagement levels were separated into Affective, Cognitive, and Behavior domains to match our integrated design framework for the research project. The experimental group who learned through play had better engagement than the control group who learned traditionally. This was seen in Affective, Cognitive, and Behavioral domains. See Figure for data visualization.

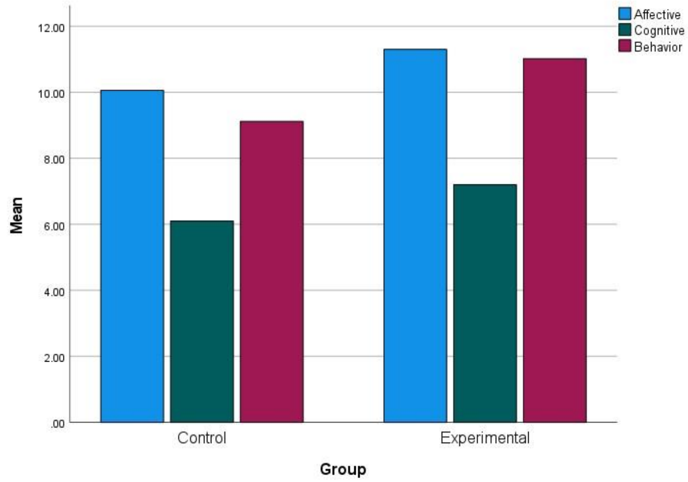

Figure 6 Data Analysis of Engagement Survey

Furthermore, graphs were plotted to investigate engagement patterns across Class, Schools, and Ages. It was concluded that the experimental group showed higher levels of all 3 engagement domains across all variables. Data is depicted in Figures below.

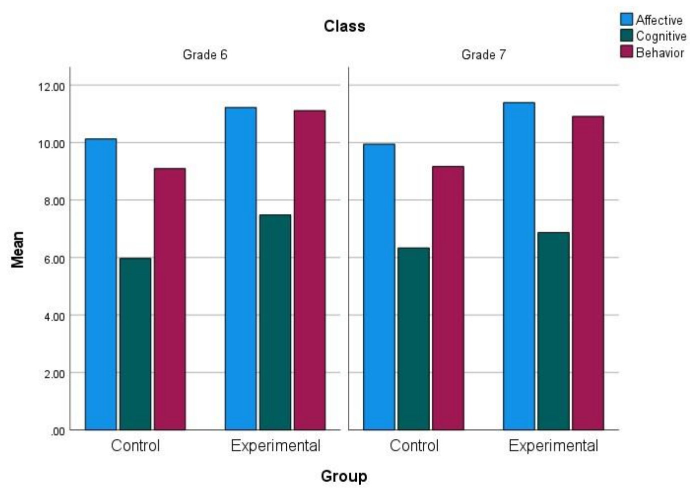

Figure 7 Engagement levels across Class

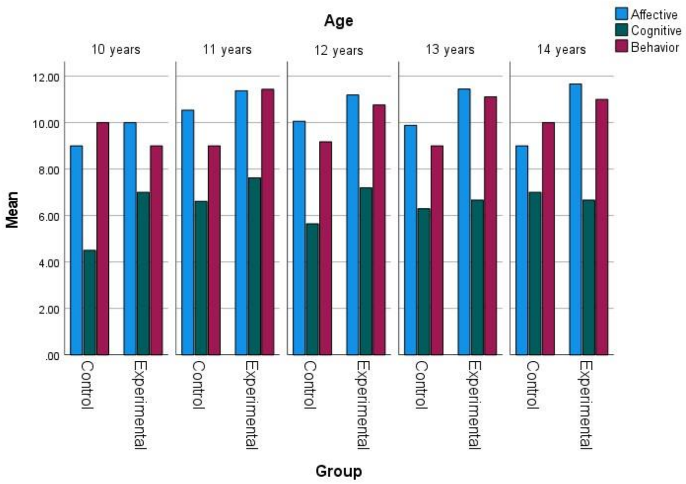

Figure 8 Engagement levels across Age

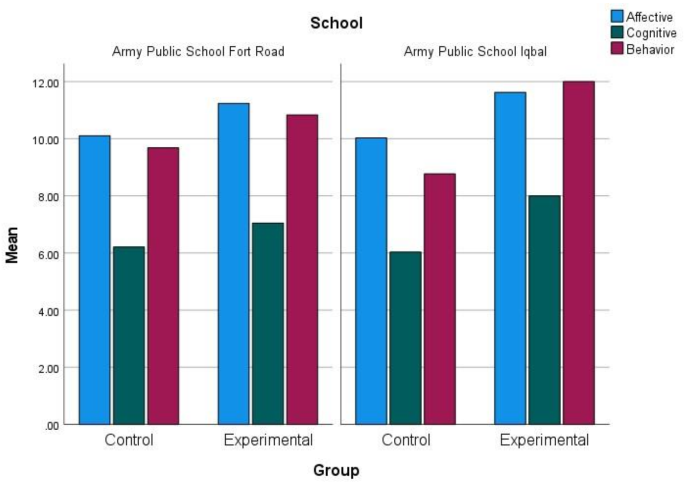

Figure 9 Engagement levels across Schools

We developed the following hypothesis to answer, "Are learning outcomes achieved through online STEM?" Tests were based on student scores from post-test MCQs.H0: Post-test scores are similar for playful and traditional methods. Post-test scores for playful and traditional methods are not similar. Normality tests were done on 50-value control and experimental group data to determine if parametric or non-parametric statistical tests were needed. SPSS uses the Shapiro Wilk test for normalcy. Traditional normality tests like the Kolmogorov-Smirnov and Shapiro-Wilk are shown here. The Shapiro-Wilk Test works well with small sample sizes (<= 50) but can handle up to 2000 samples. Data is normal if the Shapiro-Wilk Test Sig. is larger than 0.05. Below 0.05, the data deviates significantly from a normal distribution. The tables below show that "Score" is not regularly distributed for control and experimental groups.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Score	50	100.0%	0	0.0%	50	100.0%

Figure 10 Normality Control Group Data A

Descriptive

			Statistic	Std. Error
Score	Mean		4.36	.106
	95% Confidence Interval for Mean	Lower Bound	4.15	
		Upper Bound	4.57	
	5% Trimmed Mean		4.44	
	Median		4.00	
	Variance		.562	
	Std. Deviation		.749	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		1	
	Skewness		-1.316	.337
	Kurtosis		2.166	.662

Figure 11 Normality Control Group Data B

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wi k		
Course	Statistic	df	Sig.	Statistic	df	Sig.
Score	.283	50	.000	.732	50	.000

Figure 12 Normality Control Group Data C

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Score	50	100.0%	0	0.0%	50	100.0%

Figure 13 Normality Experimental Group Data A

Descriptive				
			Statistic	Std. Error
Score	Mean		3.60	.185
	95% Confidence Interval for Mean	Lower Bound	3.23	
		Upper Bound	3.97	
	5% Trimmed Mean		3.66	
	Median		4.00	
	Variance		1.714	
	Std. Deviation		1.309	
	Minimum		1	
	Maximum		5	
	Range		4	
	Interquartile Range		3	
	Skewness		-.341	.337
	Kurtosis		-1.305	.662

Figure 14 Normality Experimental Group Data B

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wi k		
	Statistic	df	Sig.	Statistic	df	Sig.
Score	.218	50	.000	.847	50	.000

Figure 15 Normality Experimental Group Data C

Data analysis required non-parametric testing due to non-normality. On-parametric Mann-Whitney Parametric t-test can be replaced by U test. A nonparametric test checks the null hypothesis that two samples are from the same population (i.e., have the same mean) or that one sample is larger.H0: Equal population vs. H1: Unequal population. Student learning outcomes were analyzed using Mann-Whitney nonparametric test. These variables were examined using post-test MCQ scores. Details follow. Variable scores across control and experimental groups tested the following assumptions.H0: Experimental and control post-test results are similar. Ha: Experimental and control post-test scores differ. The null hypothesis failed statistically. The control and experimental groups adopting standard and playful pedagogy had different post-test scores. Control Group scored higher. The tables below show test results.

Hypothesis Test Summary			
Null Hypothesis	Test	Sig.[a,b]	Decision
The distribution of Score is the same across categories of Group	Independent-Samples Mann-Whitney U Test	.005	Reject the null hypothesis

Independent-Samples Mann-Whitney U Test Summary	
Total N	100
Mann-Whitney U	870.000
Wilcoxon W	2145.000
Test Statistic	870.000
Standard Error	136.807
Standardized Test Statistic	-2.778
Asymptotic Sig. (2-sided test)	.005

Figure 16 Mann-Whitney Test across Groups Representation A

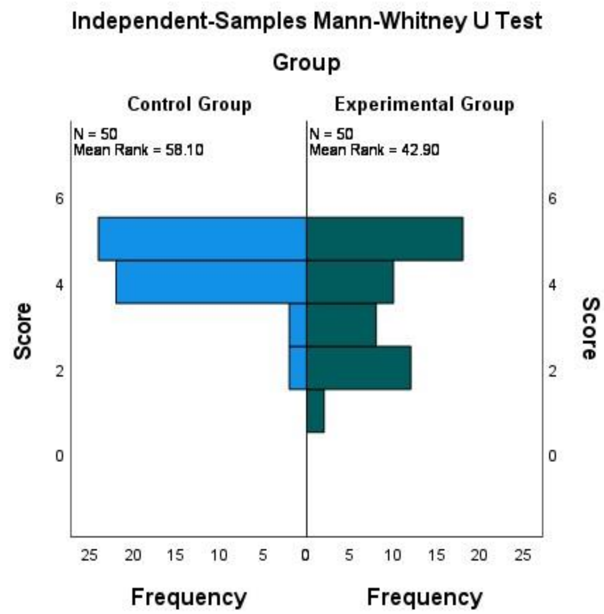

Figure 17 Mann-Whitney Test across Groups Representation B

Army Public School was tested and the variable score at Army Public School (Nowshera) and Army Public School Fort Road (Rawalpindi) to confirm the following hypothesis.

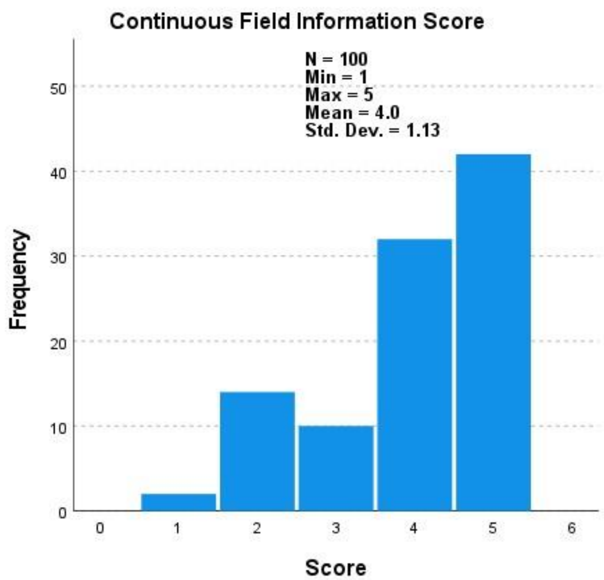

Figure 18 Continuous Field Information Score

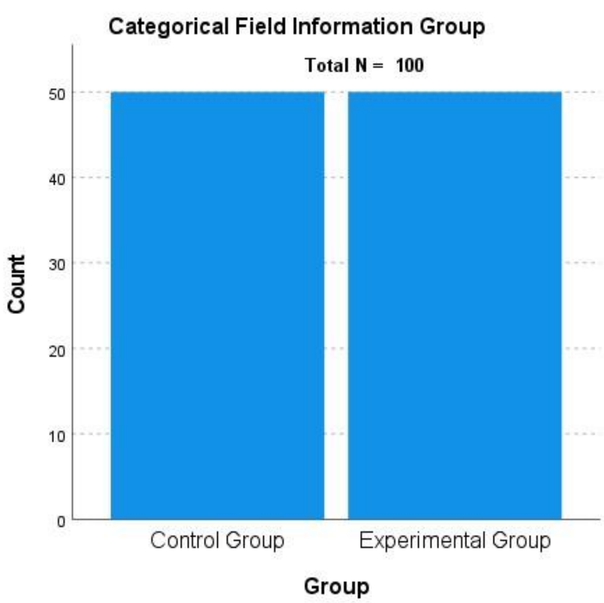

Figure 19 Categorical Field Information Group

H0: Army Public School Rawalpindi and Nowshera post-test scores are similar. Ha: Rawalpindi and Nowshera Army Public School post-test scores are not same. The null hypothesis survived statistical testing. Post-test scores were similar for both research schools. Students from different schools scored similarly. APS Rawalpindi had more participants than Nowshera due to its larger student population. Test results are in tables below.

Hypothesis Test Summary			
Null Hypothesis	Test	Sig.^{a,b}	Decision
The distribution of Score is the same across categories of School	Independent-Samples Mann-Whitney U Test	.637	Retain the null hypothesis

Independent-Samples Mann-Whitney U Test Summary	
Total N	100
Mann-Whitney U	1126.500
Wilcoxon W	1906.500
Test Statistic	1126.500
Standard Error	133.455
Standardized Test Statistic	-.472
Asymptotic Sig. (2-sided test)	.637

Figure 20 Mann-Whitney Test across Schools Representation A

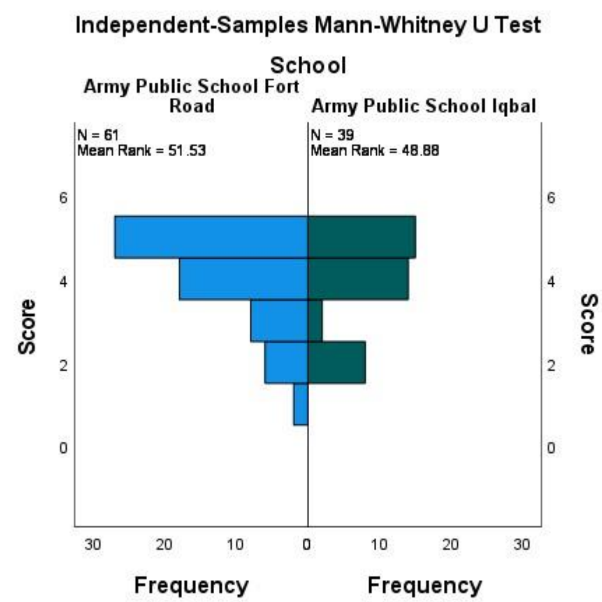

Figure 20 Mann-Whitney Test across Schools Representation B

The Kruskal Wallis test is a prominent nonparametric test for comparing outcomes between multiple independent groups. The Kruskal Wallis test compares medians in k comparison groups (k > 2) and is frequently called an ANOVA with ranks. The following research hypotheses were tested using the Kruskal Wallis test on variable scores across 11-14-

year-olds. The number of participants was 100.H0: Post-test scores are similar for 11-14-year-olds. Ha: 11-14-year-olds' post-test scores are modest. The null hypothesis survived statistical testing. Post-test scores were high for all 11-14-year-olds. Test results are in the tables below. Figure Kruskal-Wallis Test across Ages.

Hypothesis Test Summary			
Null Hypothesis	Test	Sig.[a,b]	Decision
The distribution of Score is the same across categories of Age	Independent-Samples Kruskal-Wallis Test	.456	Retain the null hypothesis

Independent-Samples Kruskal-Wallis Test Summary	
Total N	100
Test Statistic	3.644a, b
Degree of Freedom	4
Asymptotic Sig. (2-sided test)	.456

Figure 21 Kruskal-Wallis Test across Ages

This study compared two teaching methods, one traditional and the other using virtual robots, in online learning during the COVID lockdown. The focus was on STEM education. Both groups learned the same content, with the experimental group incorporating robotics into their lessons, while the control group followed traditional methods. Students in Grade 6 and 7 from Army Public Schools were part of the study, with 50 in each group (N=100). The control group received traditional online teaching, while the experimental group engaged in more interactive, playful learning. Designing and delivering playful lessons took more time and effort than traditional lessons. The experimental group's lesson took longer due to increased student engagement with the online robotics platform. Introducing robotics required connecting it to everyday devices like computers, televisions, washing machines, and microwaves, which made it easier for students to understand coding principles. They used block-based coding to program robots for challenges on the online learning platform. To ensure fairness in teaching STEM, real-life examples were used in both groups to maintain focus and achieve learning objectives. Structuring playful lessons was a challenge, but the teacher facilitated learning through play, offered feedback, and guided students to make discoveries while maintaining lesson objectives and engagement. The aim was for students to learn through play and exploration rather than passive knowledge transfer from the teacher. In conclusion, this study highlighted the benefits of playful learning in STEM education and emphasized the importance of engaging and interactive teaching methods. Future research should further explore this approach and improve assessment techniques. The study aimed to answer two research questions through post-tests in both the control and experimental groups.

**Research Question 1: ** Does using playful learning with game elements in online STEM education enhance student engagement? The experimental group showed a substantial increase in engagement, as seen in graphical representations. There was a significant difference in engagement survey results between the control and experimental groups. This suggests that using playful learning with game elements positively impacts student engagement across emotional, cognitive, and behavioral aspects.

**Research Question 2: ** Do students achieve their learning goals in online STEM education? After implementing online research, a multiple-choice question (MCQ) post-test was conducted through Google Forms. We tested two hypotheses: - Null Hypothesis (H0): Students in both playful and traditional learning methods score similarly in the post-test. - Alternative Hypothesis (Ha): Students in playful and traditional learning methods score differently in the post-test. The analysis rejected the null hypothesis. There was a significant difference in scores between the control and experimental groups. Students in the control group, taught through traditional methods, scored higher in the MCQ post-test, suggesting that traditional methods were more effective in assessing student learning. When we looked at other factors like school, age, and grade, they did not appear to impact the scores. The main difference was observed between the control and experimental groups, with traditional methods yielding higher scores in the MCQs. The main goal of this study was to determine if students learned when STEM concepts were taught online. We used test scores as a measure of learning, but tests may not provide the full picture. They can measure some learning, but they might not capture everything students have learned. Traditional tests tend to focus on specific types of learning and are not great at evaluating critical thinking and creativity. Instead, we should focus on how well students remember what they've learned in the long term. In our research, the test we used might not be the best way to assess learning and skills because it only asked multiple-choice questions and didn't evaluate how well students performed. Performance assessments, on the other hand, aim to measure students' originality and their ability to solve real challenges using what they've learned. These assessments focus on critical thinking, reasoning, and applying knowledge to real-world problems. STEM education has become more popular, but finding the right ways to assess learning in this interdisciplinary field is challenging. STEM covers many subjects, and we need better methods to evaluate students' understanding across different disciplines.

IV. CONCLUSION

This research aimed to make online STEM learning engaging and effective, especially during the COVID-19 disruptions. We used a design framework that focused on creating fun and effective learning experiences, using game elements to enhance students' motivation and participation. In this study, we worked with Grade 6 and 7 students from Army Public Schools in Rawalpindi and Nowshera. Half of them were in the control group, and the other half in the experimental group. We used Microsoft Teams for online classes, a platform familiar to the students. Both groups learned about 'speed, distance, and time,' but the control group had traditional lessons with PowerPoint presentations, while the experimental group had a playful learning experience with an online robotics website (https://vr.vex.com). This website allowed students to program robots using a user-friendly block-based coding system. We investigated whether using playful learning techniques increased student engagement and led to effective learning. The data was collected through post-tests and analyzed both visually and statistically. The results showed that the experimental group had higher engagement levels than the control group. However, when it came to assessing learning, the control group performed better in multiple-choice tests. In conclusion, playful techniques can make learning more engaging, but they should complement traditional methods rather than replace them entirely. We also need better assessment techniques that go beyond testing memorization. The ideal approach is to integrate playful learning into existing curricula, and one effective way to do that is by using game elements and online robotics platforms. While playful learning in online STEM has its challenges, it offers effective learning environments and keeps students motivated. It's a valuable alternative to classroom education, especially during crises like the recent pandemic. This research opens doors for further studies in online STEM education to improve learning outcomes.

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